Simulation of Aircraft Arrest Gear with MSC.ADAMS

Feasibility Study

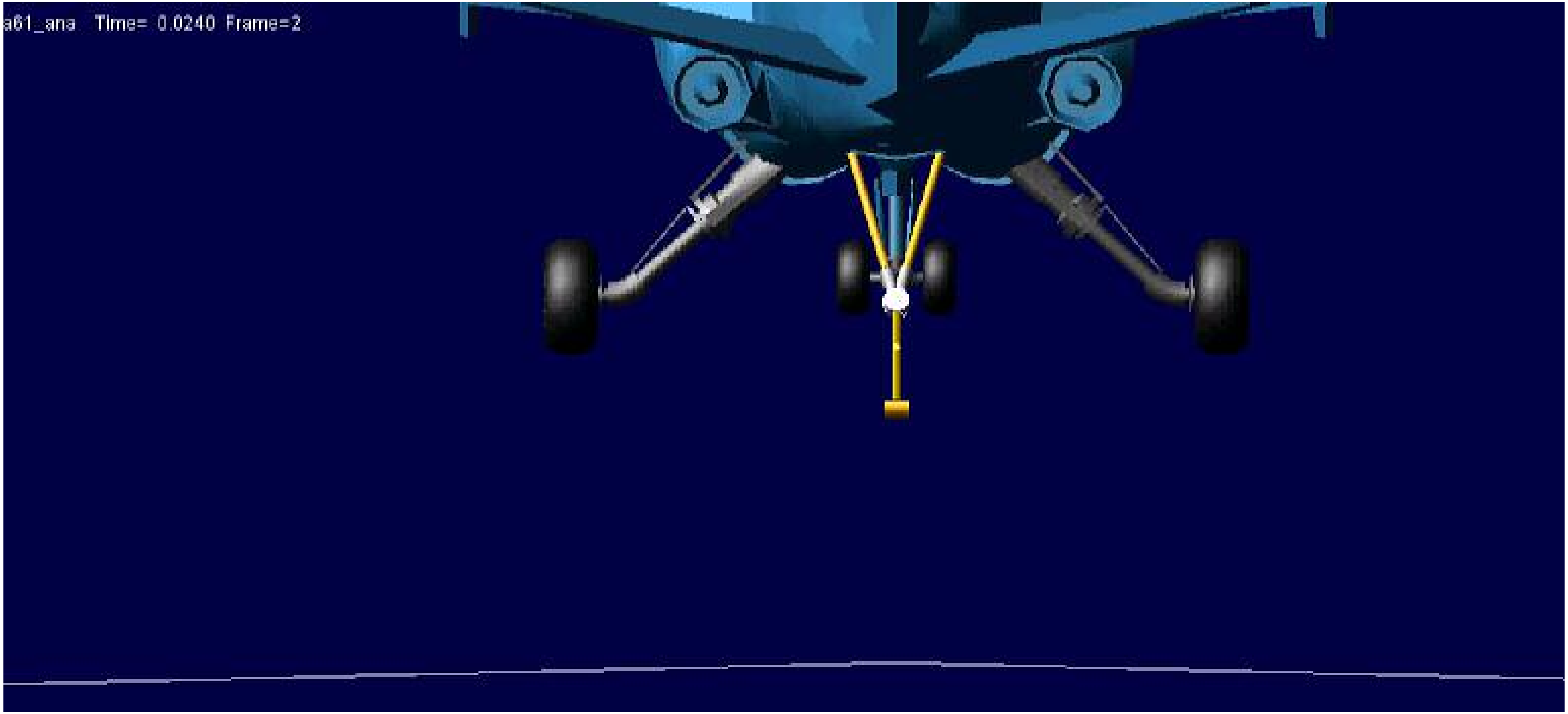
SayField International

&

MSC.Software

Problem Overview

(MSC.Software demo model)



Project Goals

1. Global model of arresting gear
    - Geometry of complete gear
    - No (or limited) lateral cable dynamics
    - Accurate description of MEC dynamics
2. Detailed model of cross-deck pendant
    - Lateral cable dynamics
    - Describe kink wave after plane impact
3. Combination of models 1. and 2.
    - Technological challenge

Project Challenges

- Cable dynamics:
  - Discrete cable model: lateral + axial dynamics
  - Spring-based cable model: axial dynamics only
  - How to combine Discrete and Spring-based ?
- Arrest gear (or MEC) model:
  - Method applied: Translate Matlab/Simulink to MSC.ADAMS syntax
- Model parameters:
  - Cable data measured and implemented

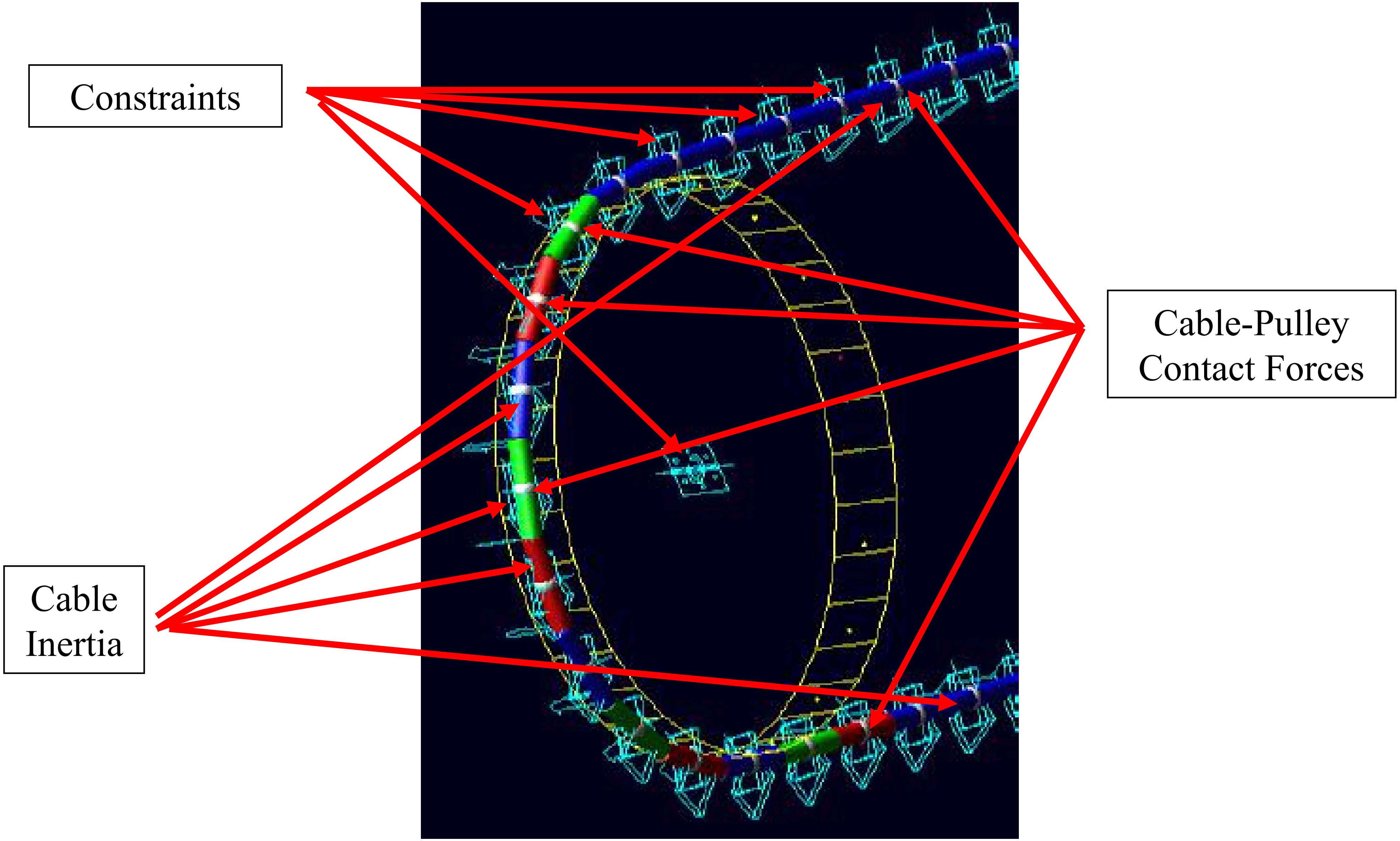
Agenda

- Cable modelling
- Cable Toolkit
- Modelling methods
- Cable Data Measurement
- Simulation Results
- Conclusions
- Further research

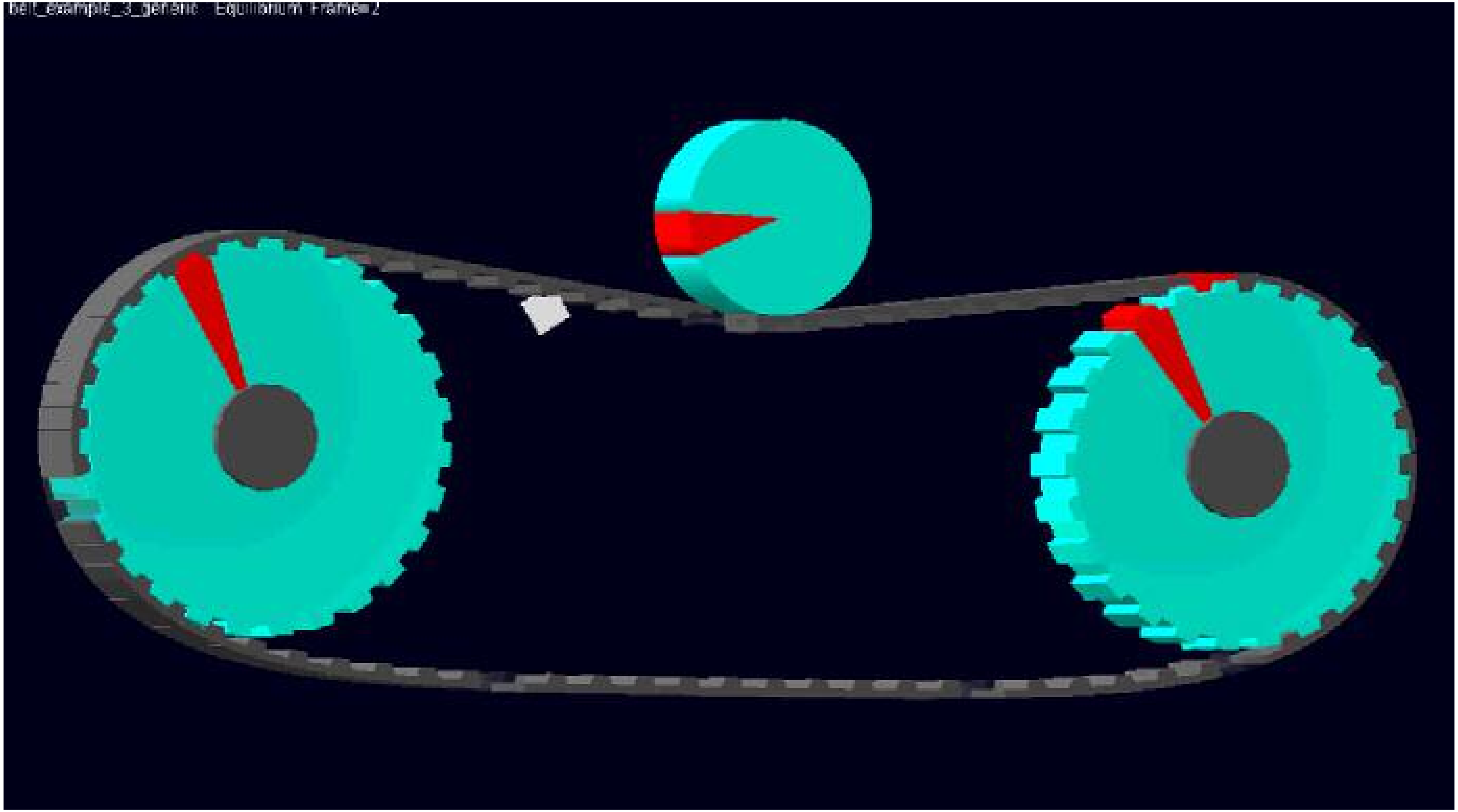
Cable model methods

- Discretized vs. Spring-based cable models
  - Discretized:
    - Cable is divided in *n* rigid parts (n > 100)
    - Pulleys (*p*) are modelled as rotating parts
    - Contact cable-pulley through impact/ gforce
    - Nr. of contacts = $n * p$
  - Spring-based:
    - Cable mass doesnot move
    - Cable mass accounted for in pulley rotation
    - Cable is essentially a massless spring-force model
    - Pulley rotations are passed through cable forces

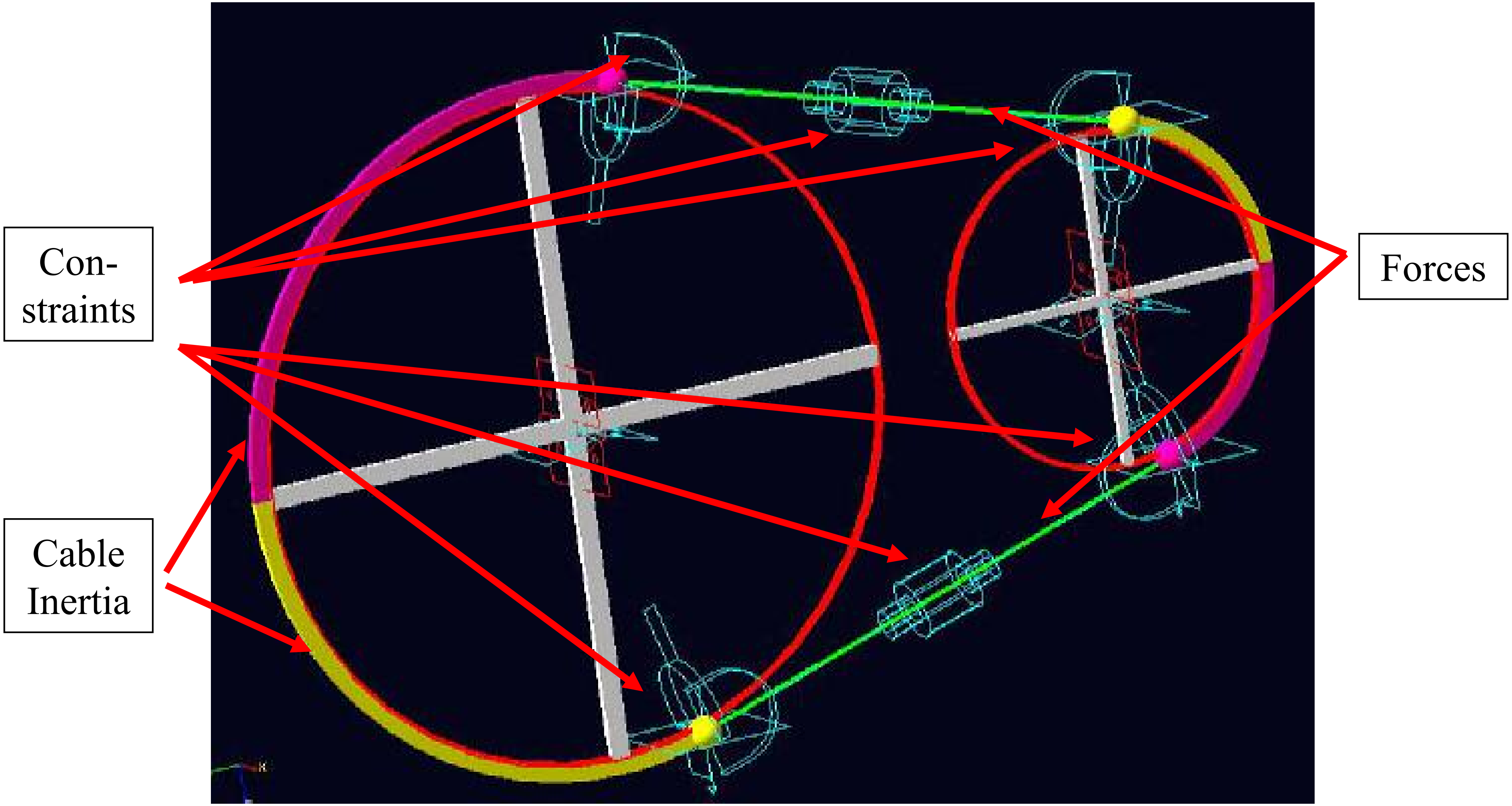
Discretized cable: parts & constraints & contacts



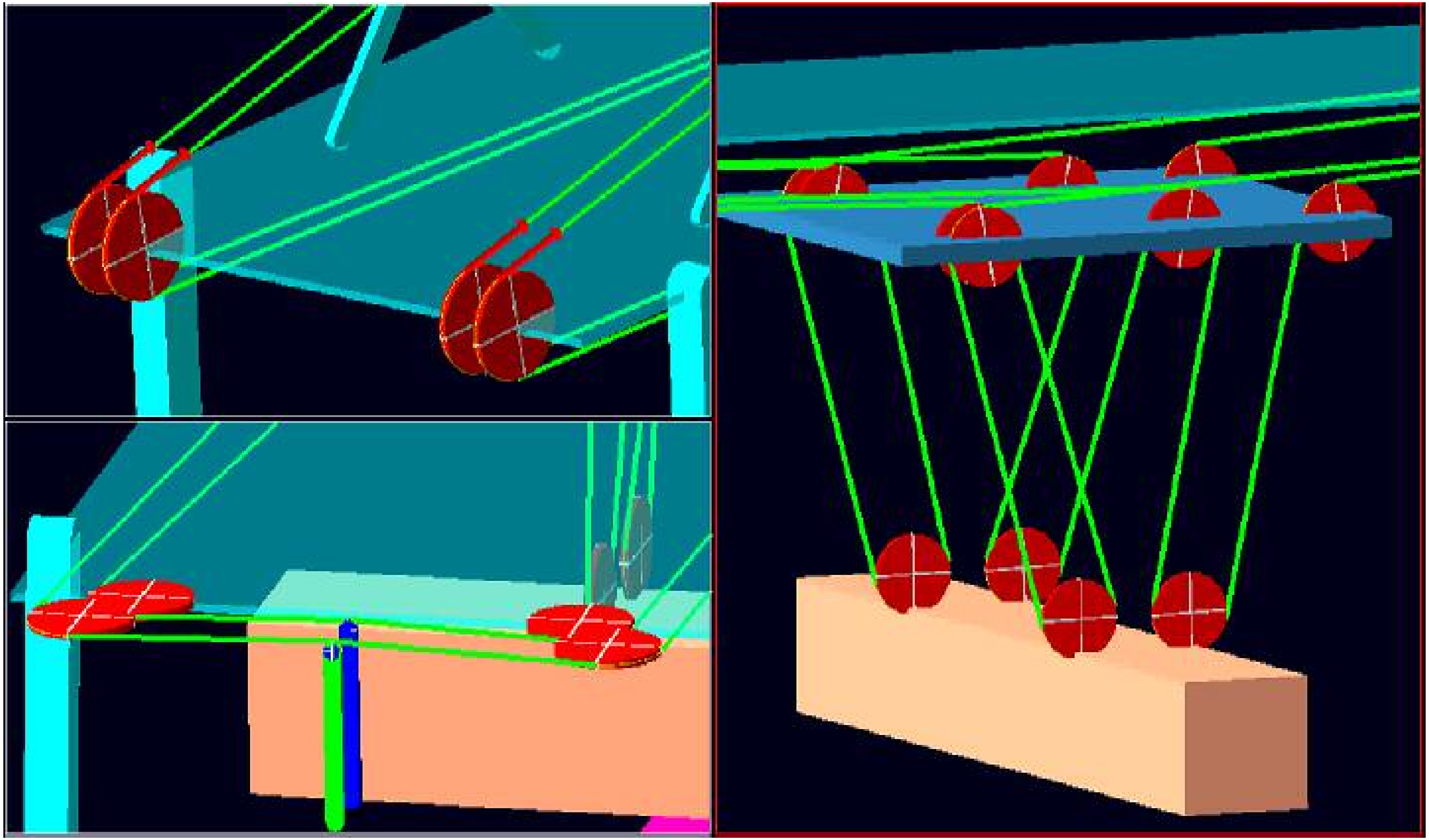
Sample discretized method (from ADAMS/Engine)



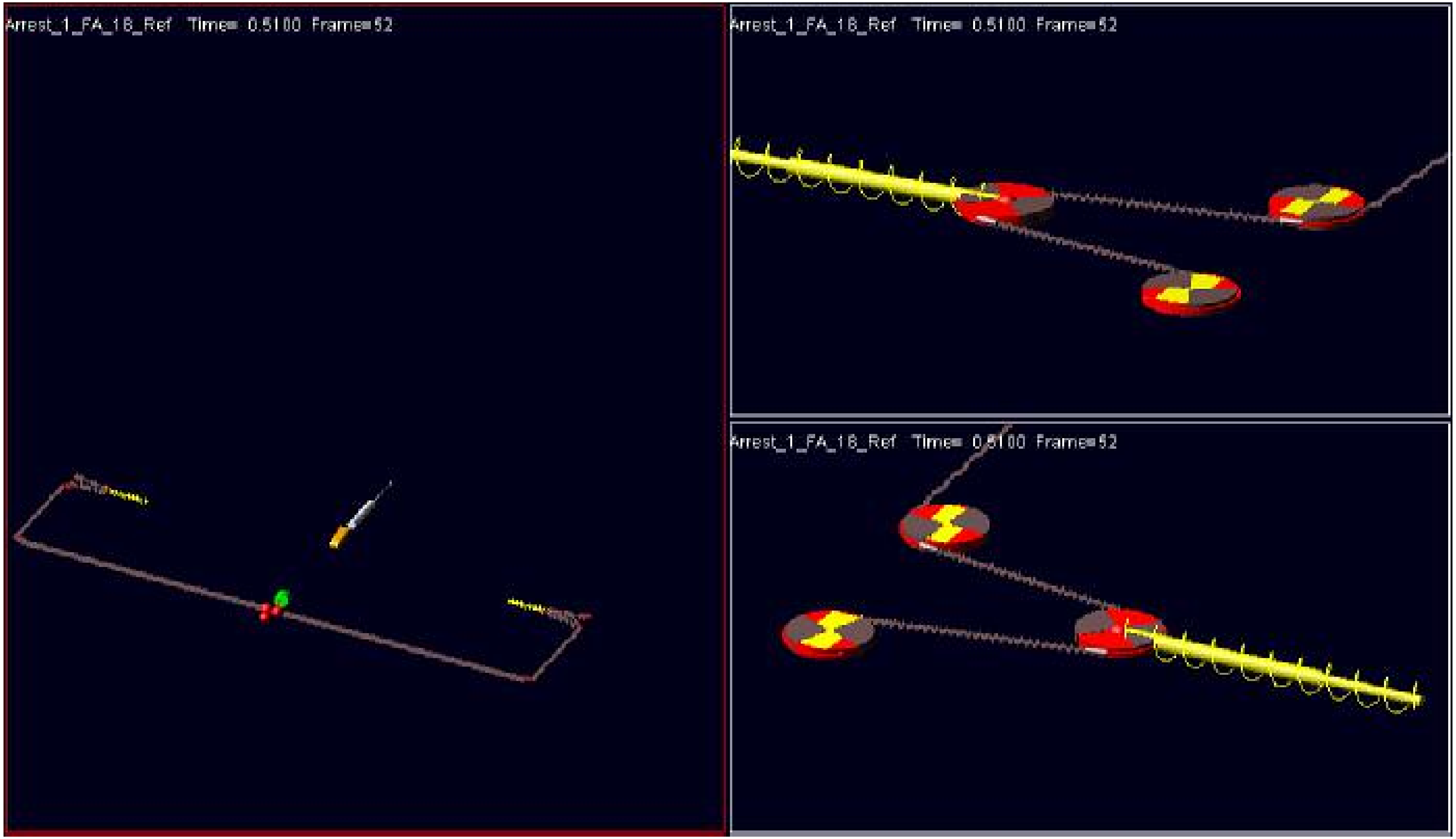
Spring-based cable: pulleys & forces & constraints



Sample Spring-based method (container crane dynamics)



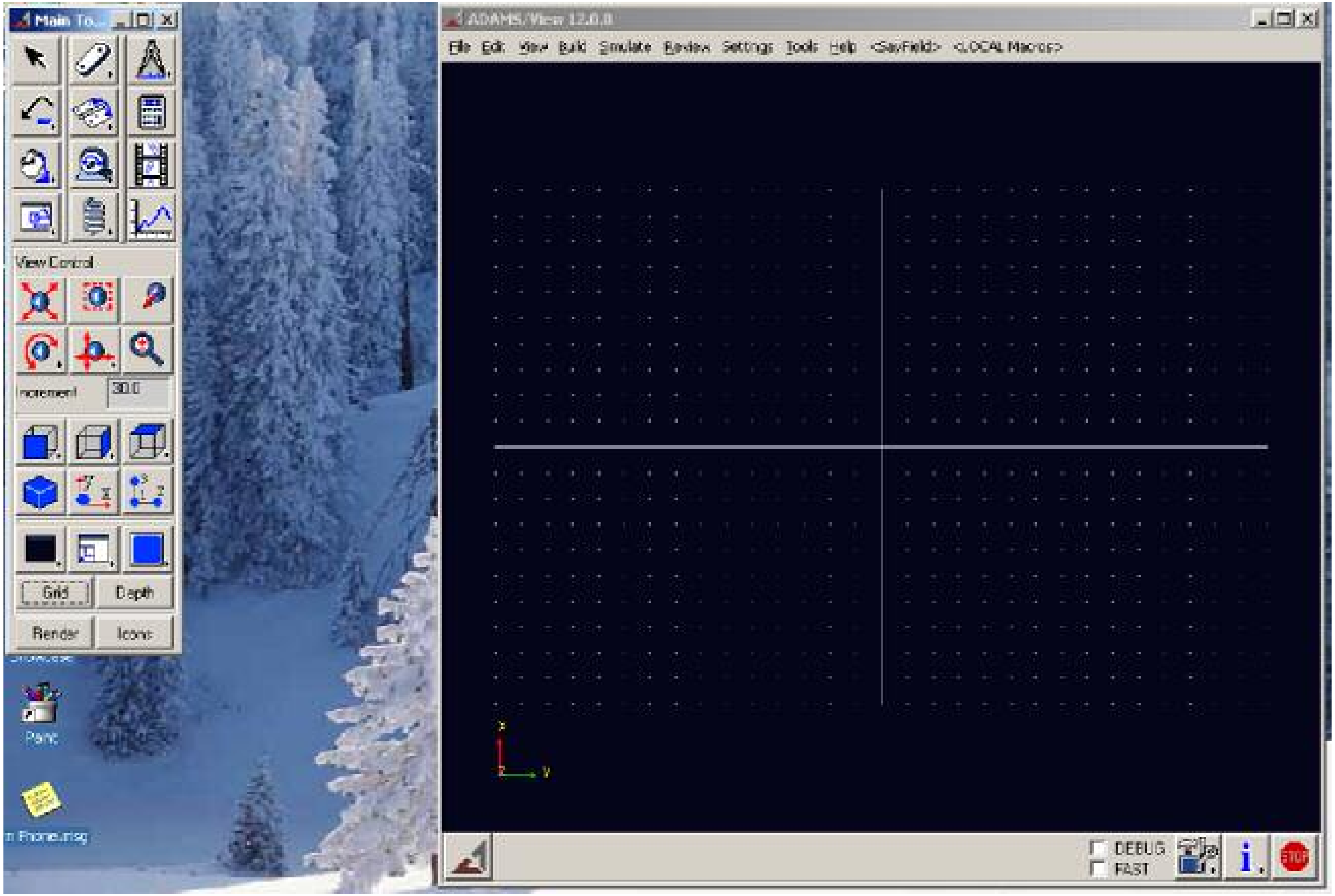
Sample Spring-based method (arrest gear model 1)



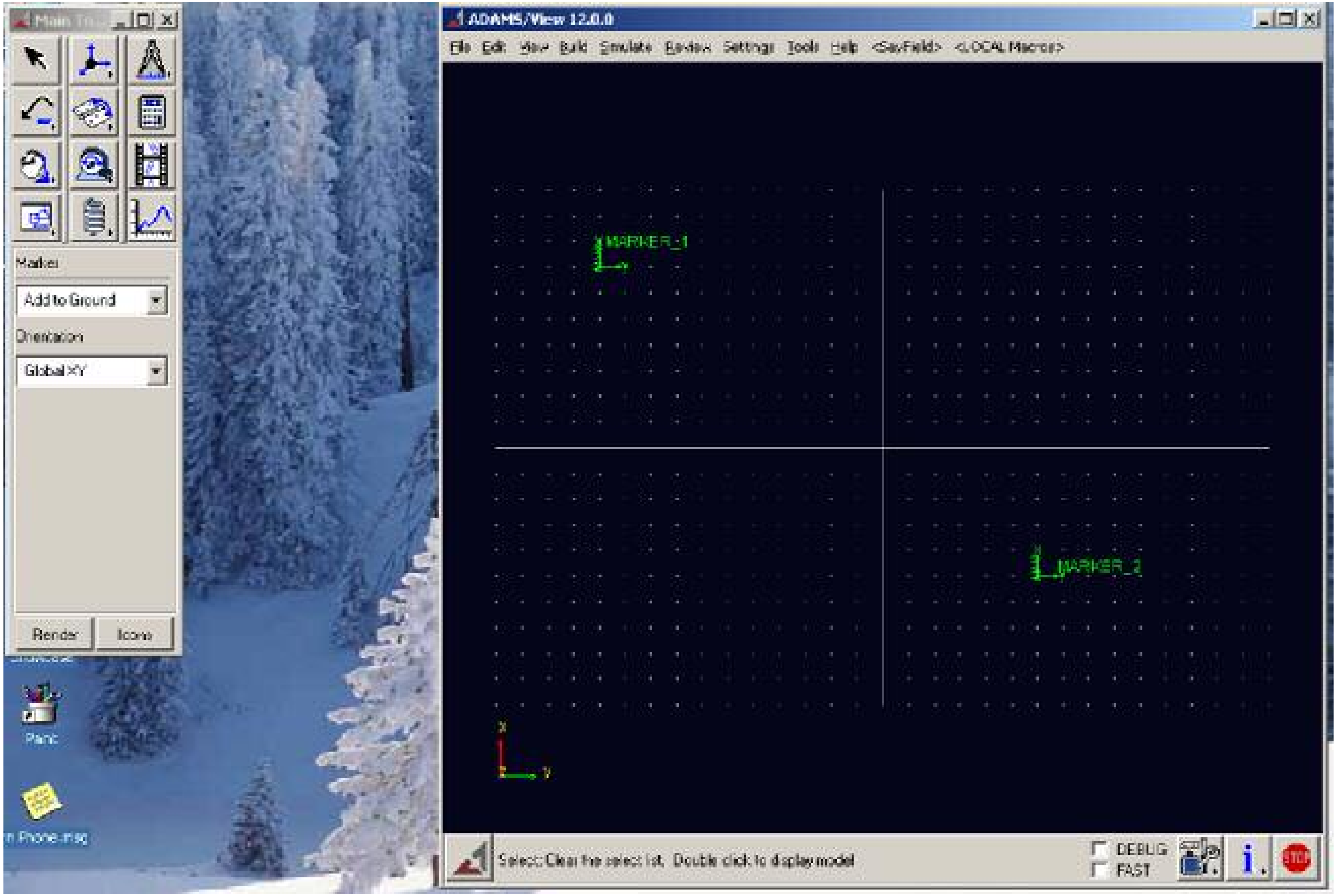
Cable & Belts Toolkit

- Customised modelling tools
- Macros and User Dialogs
- Parametrised Cable models
- Data Structures for Cables & Pulleys
- ASCII Parameter Dbase
- Spring-based & Discrete Cables

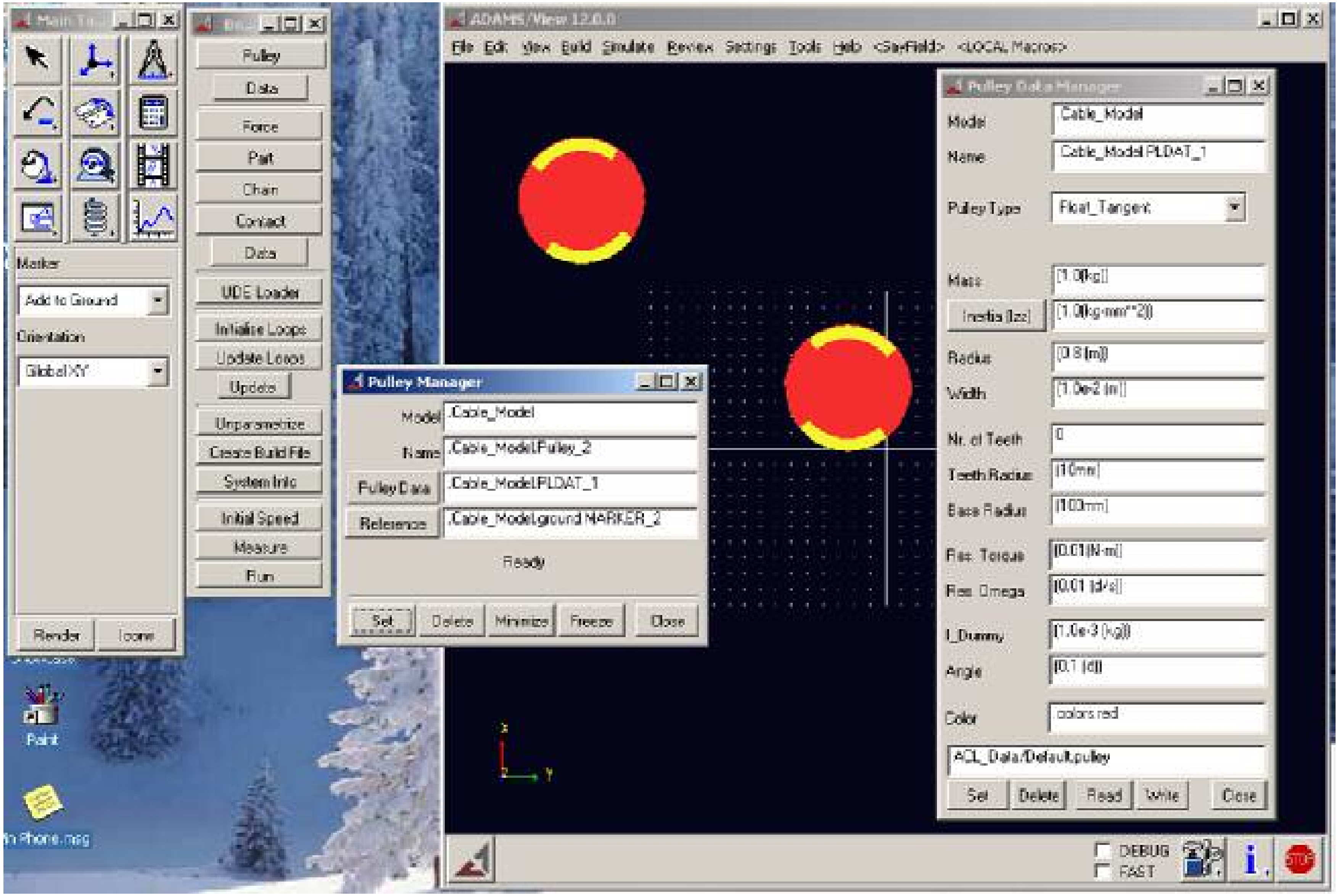
Start modelling session



Define Pulley Reference Markers

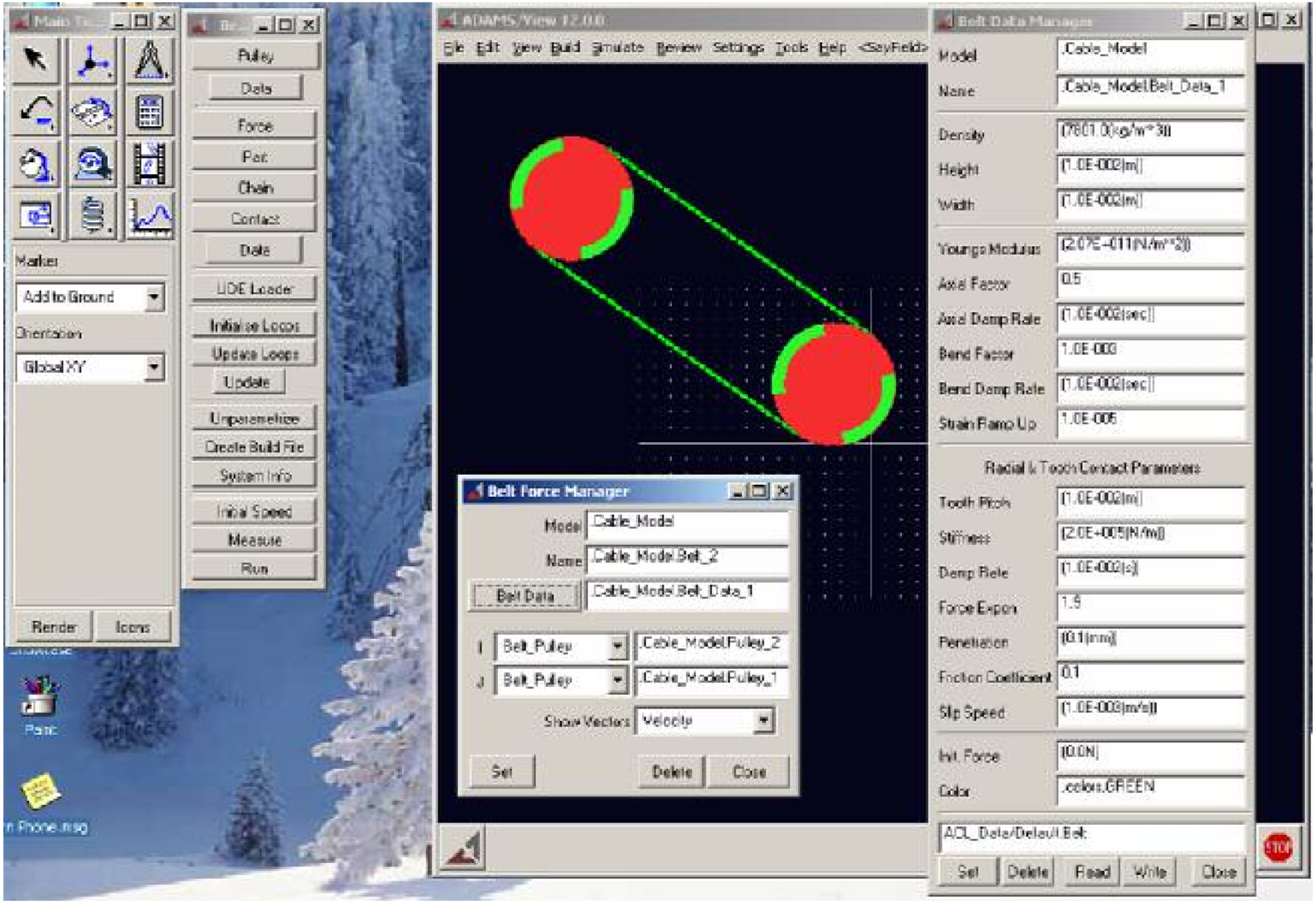


Define Pulley Data Structure & Pulleys

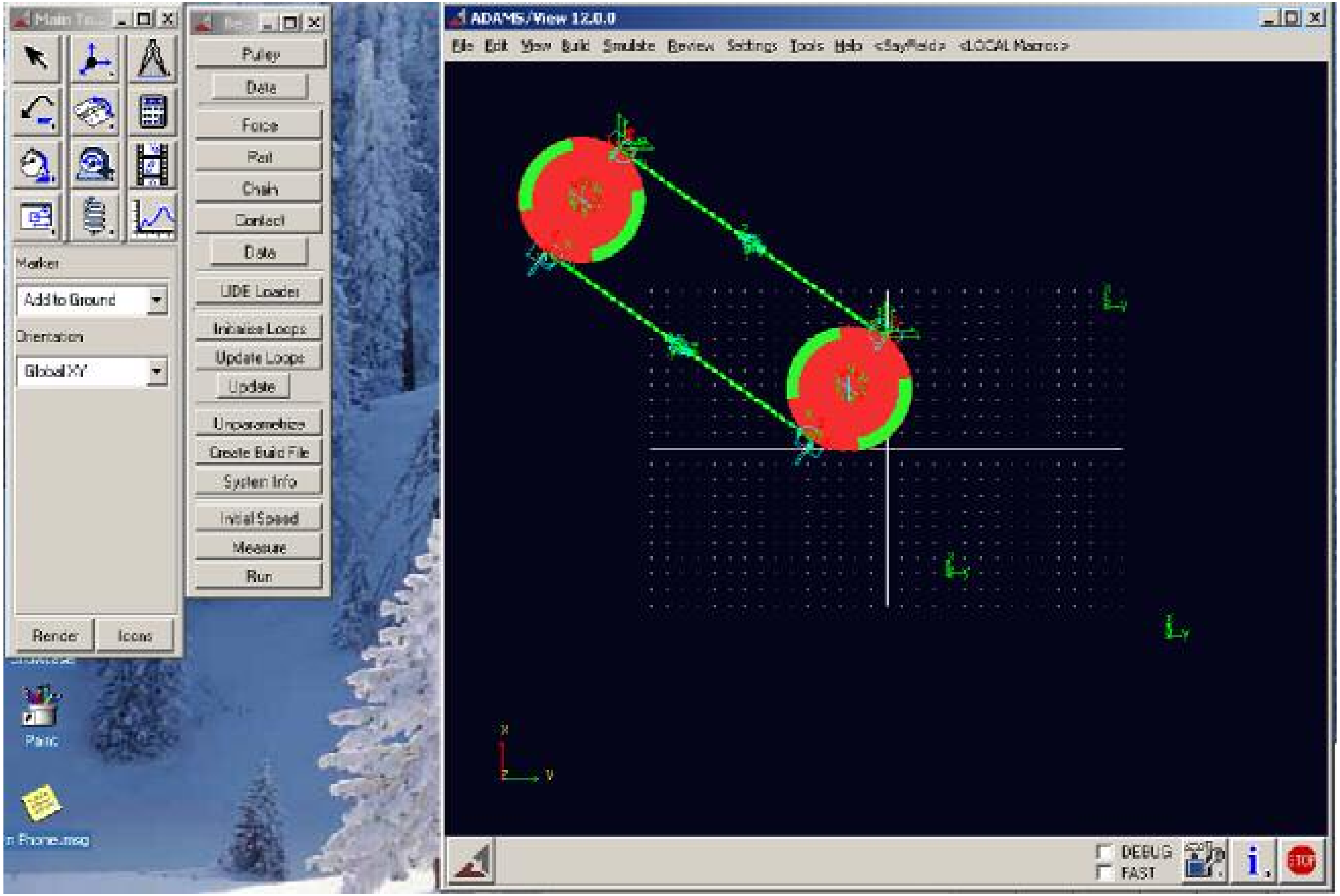


MSC SOFTWARE
SIMULATING REALITY

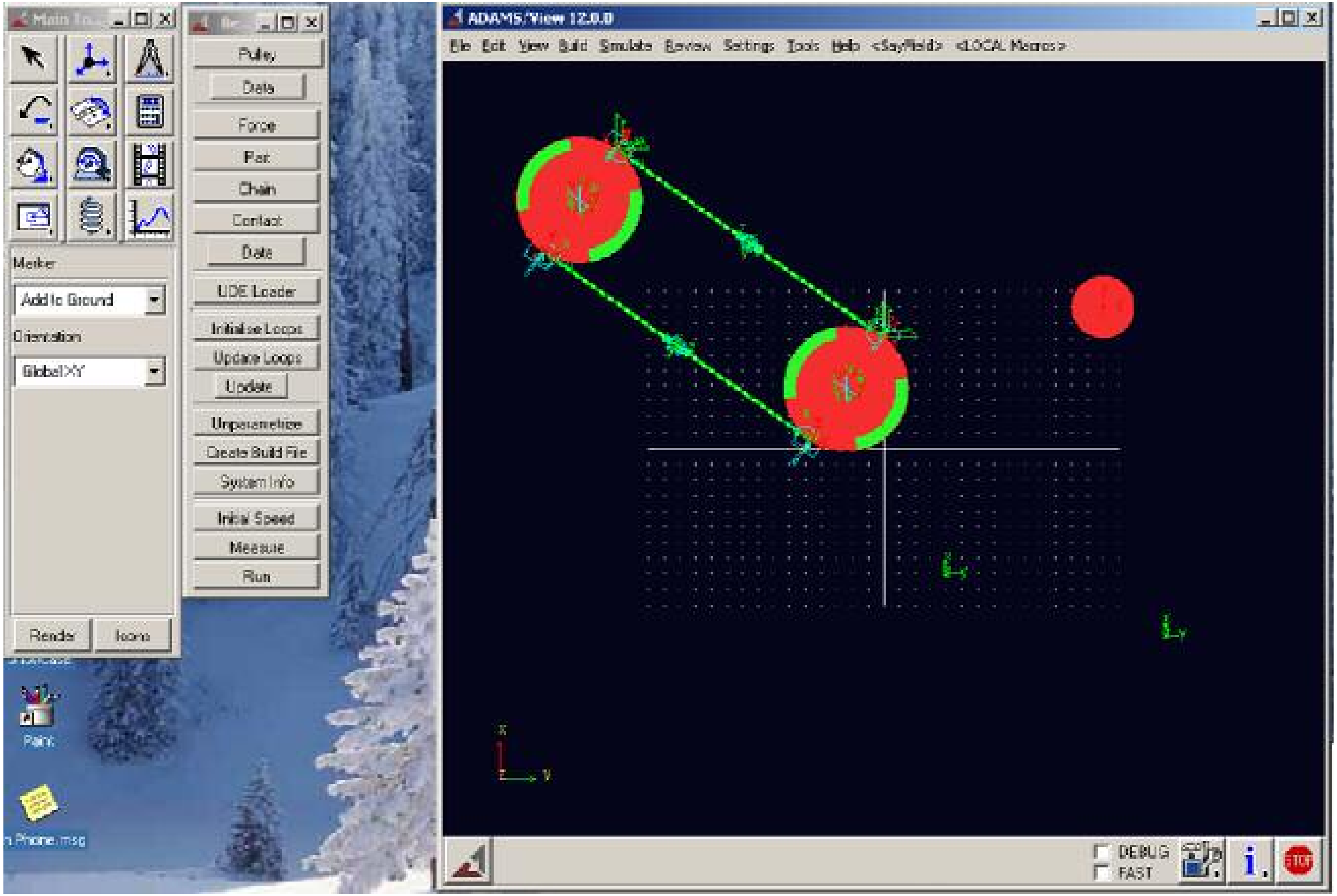
Define Cable Force Data Structure & Cables



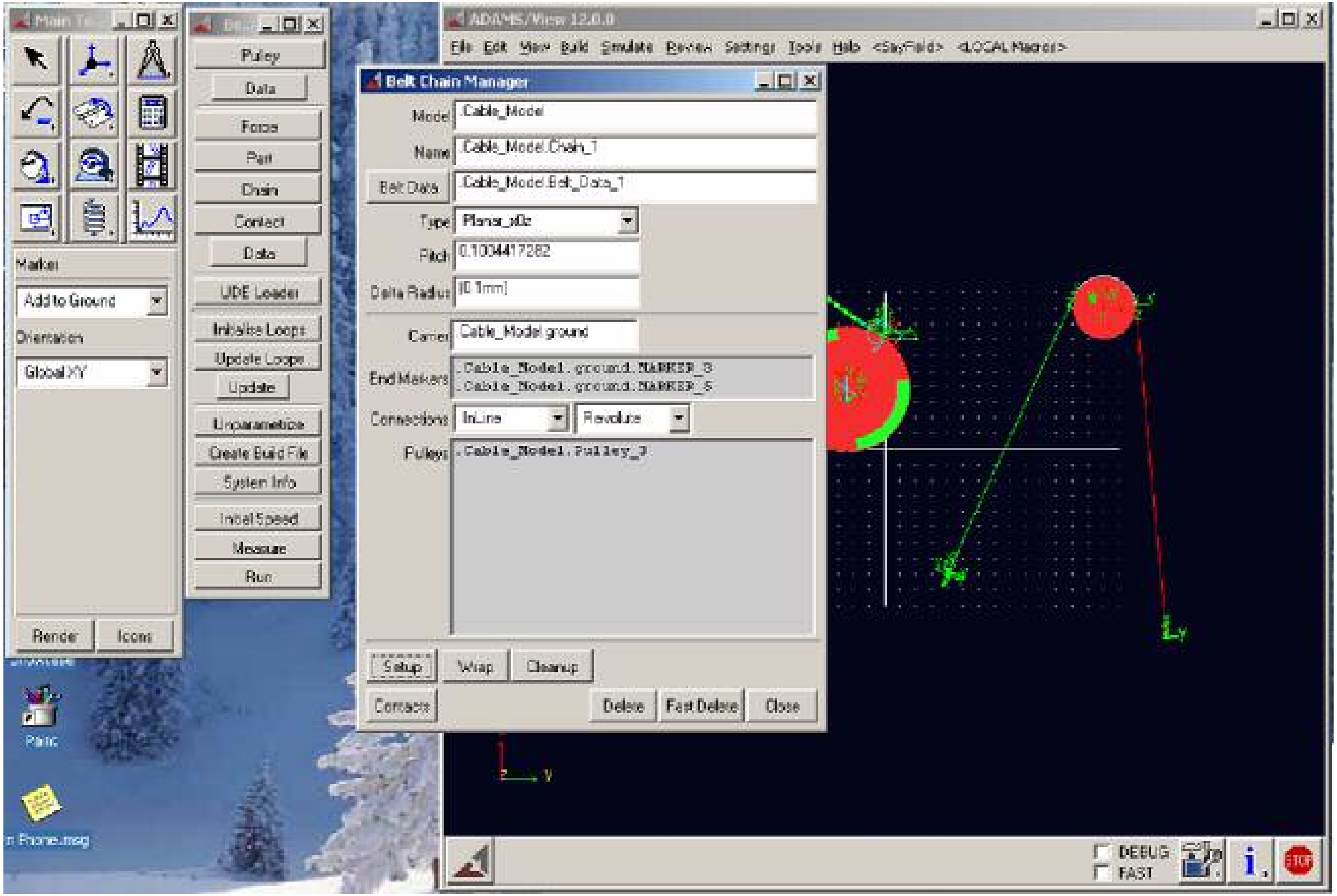
Define Markers for Discrete Cable



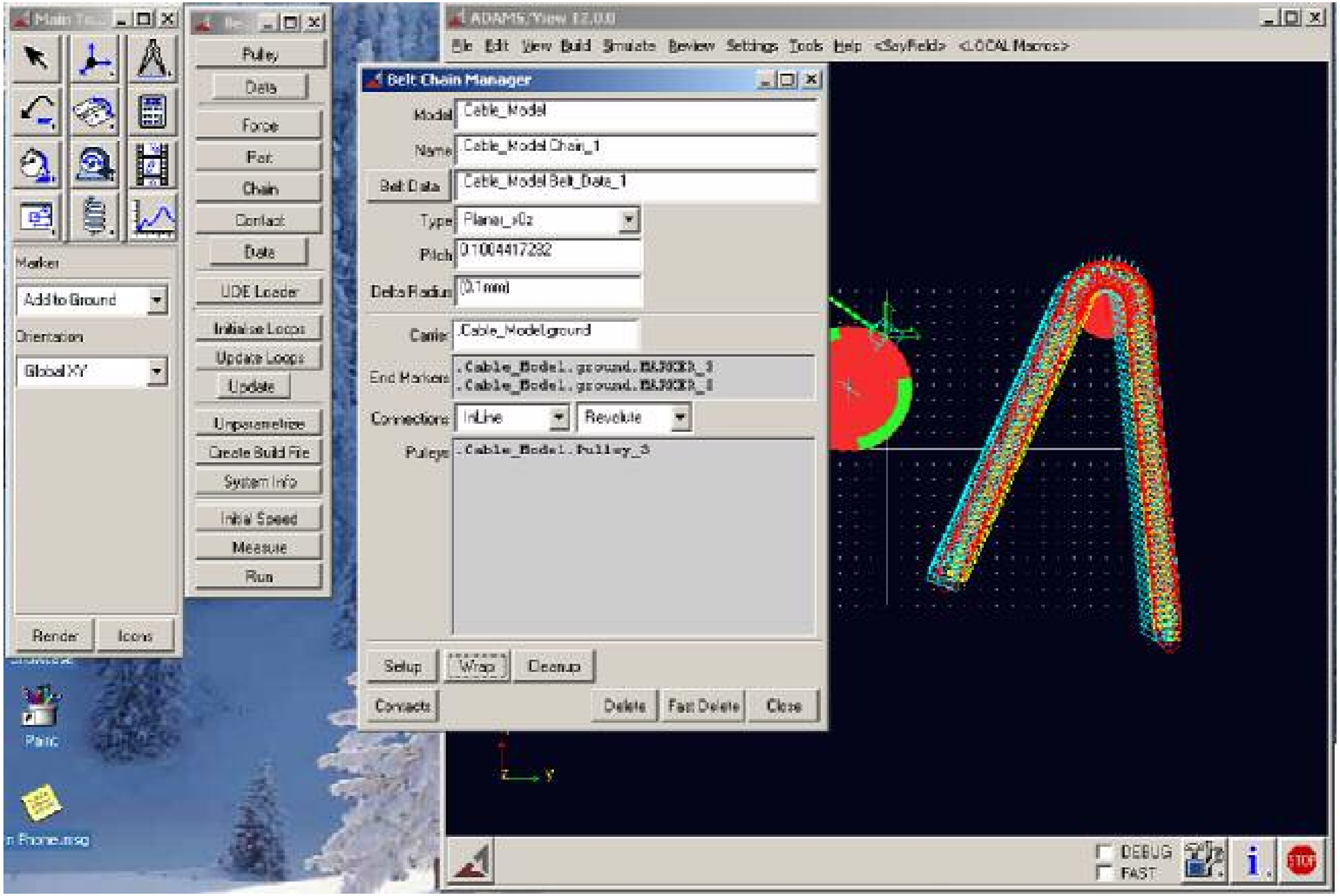
Define and Minimize Pulley



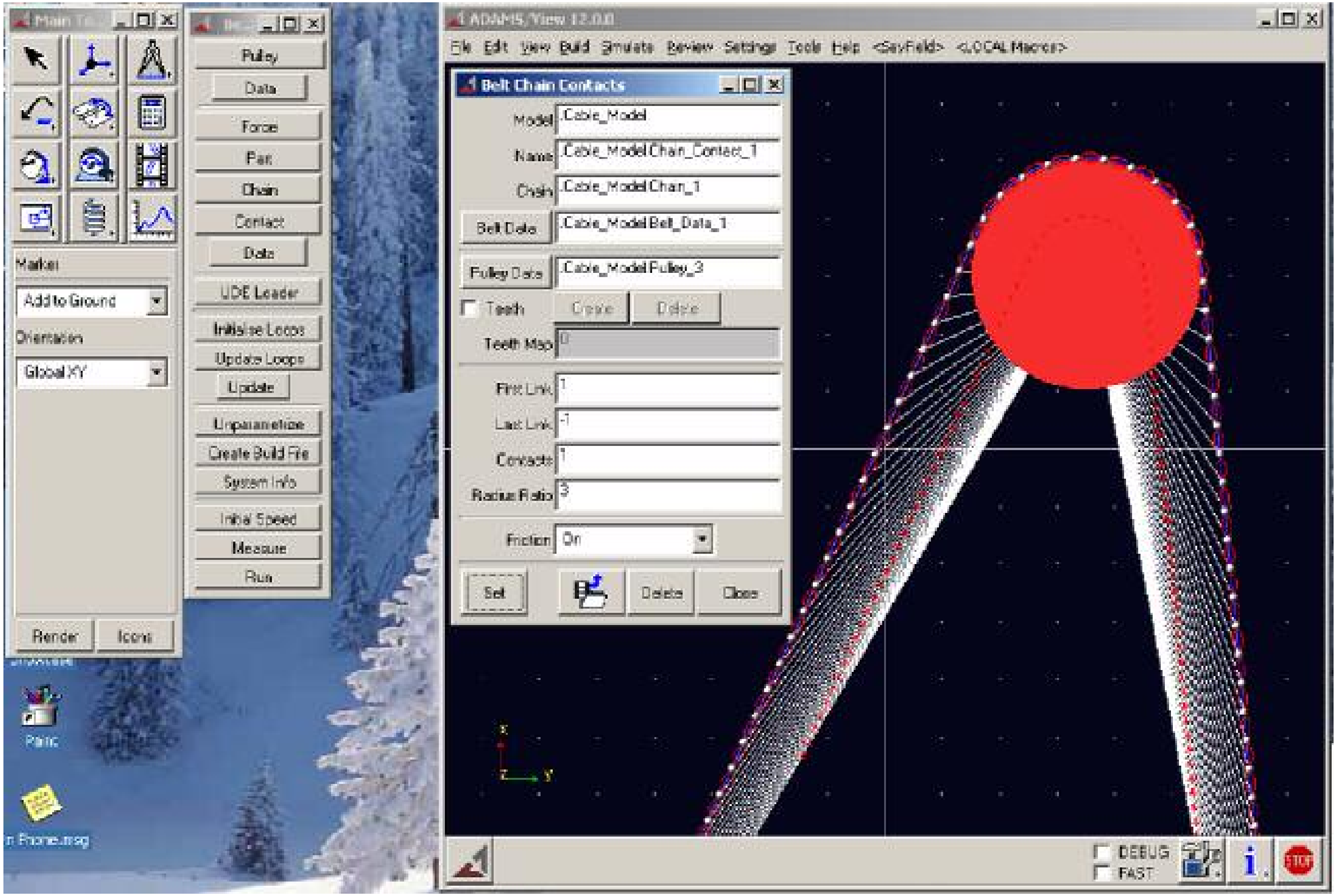
use the *Belt Chain Manager* and *Setup* the Chain



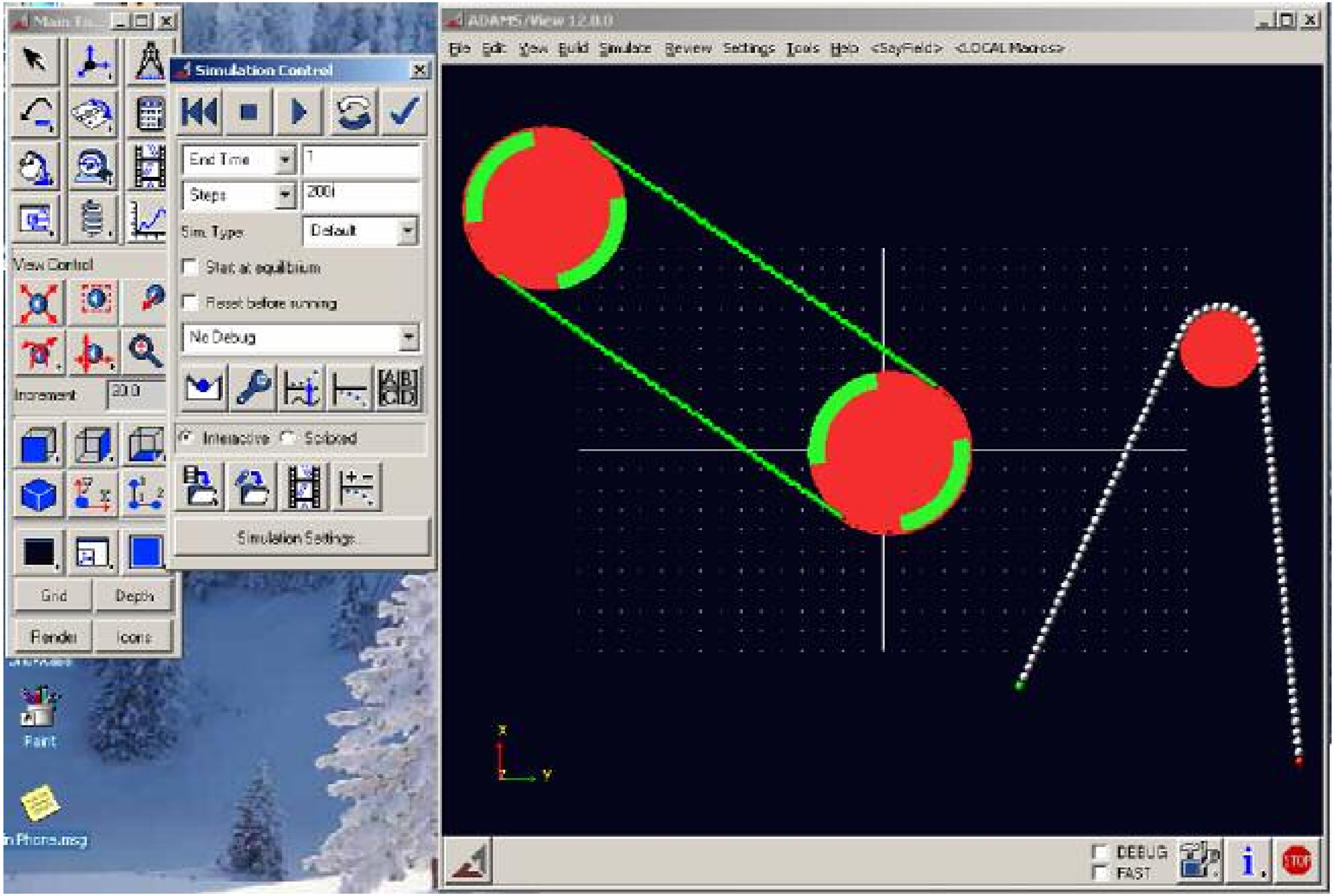
use the *Belt Chain Manager* and *Wrap* the Chain



Create contacts between chain and pulley



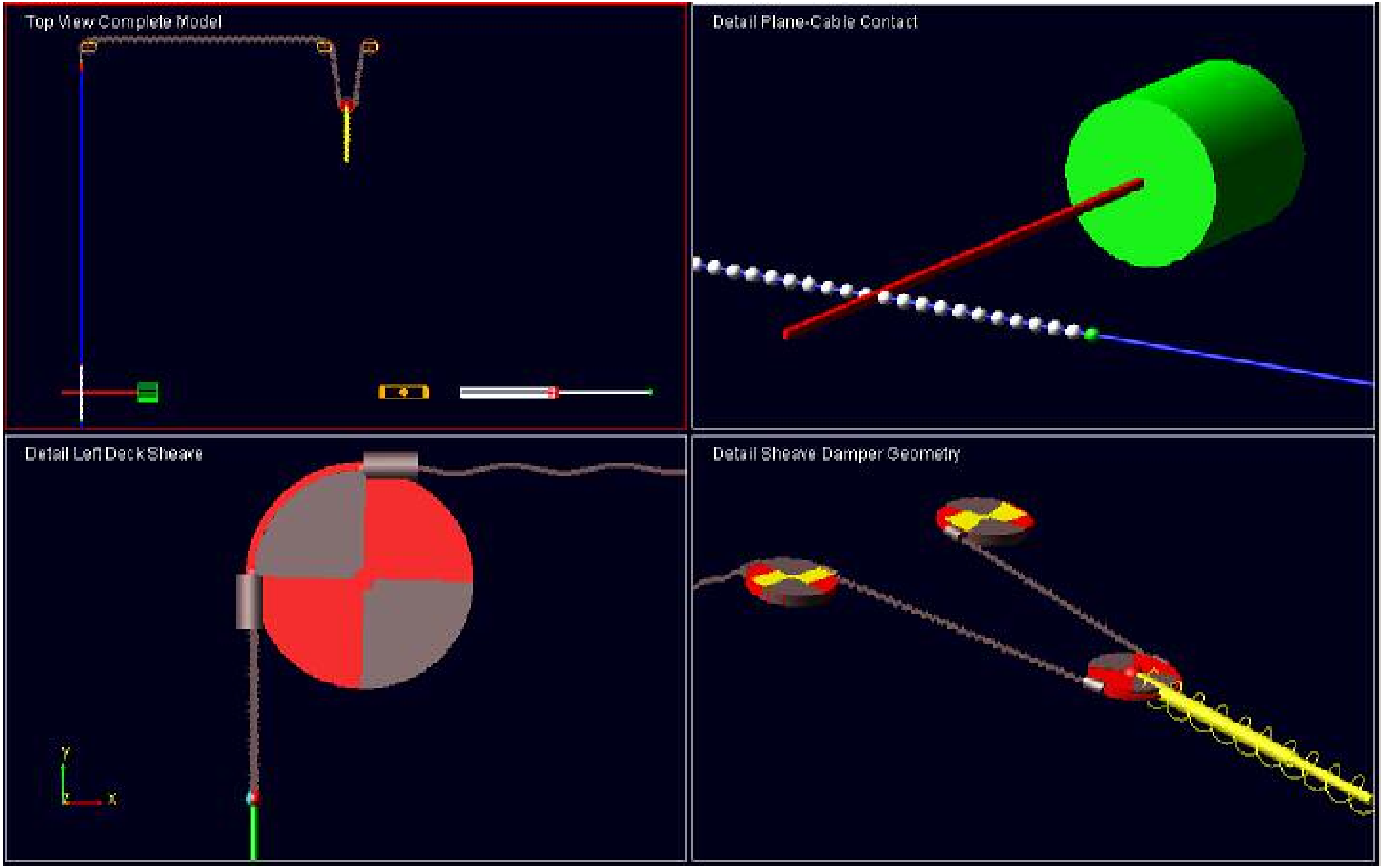
Run Simulations



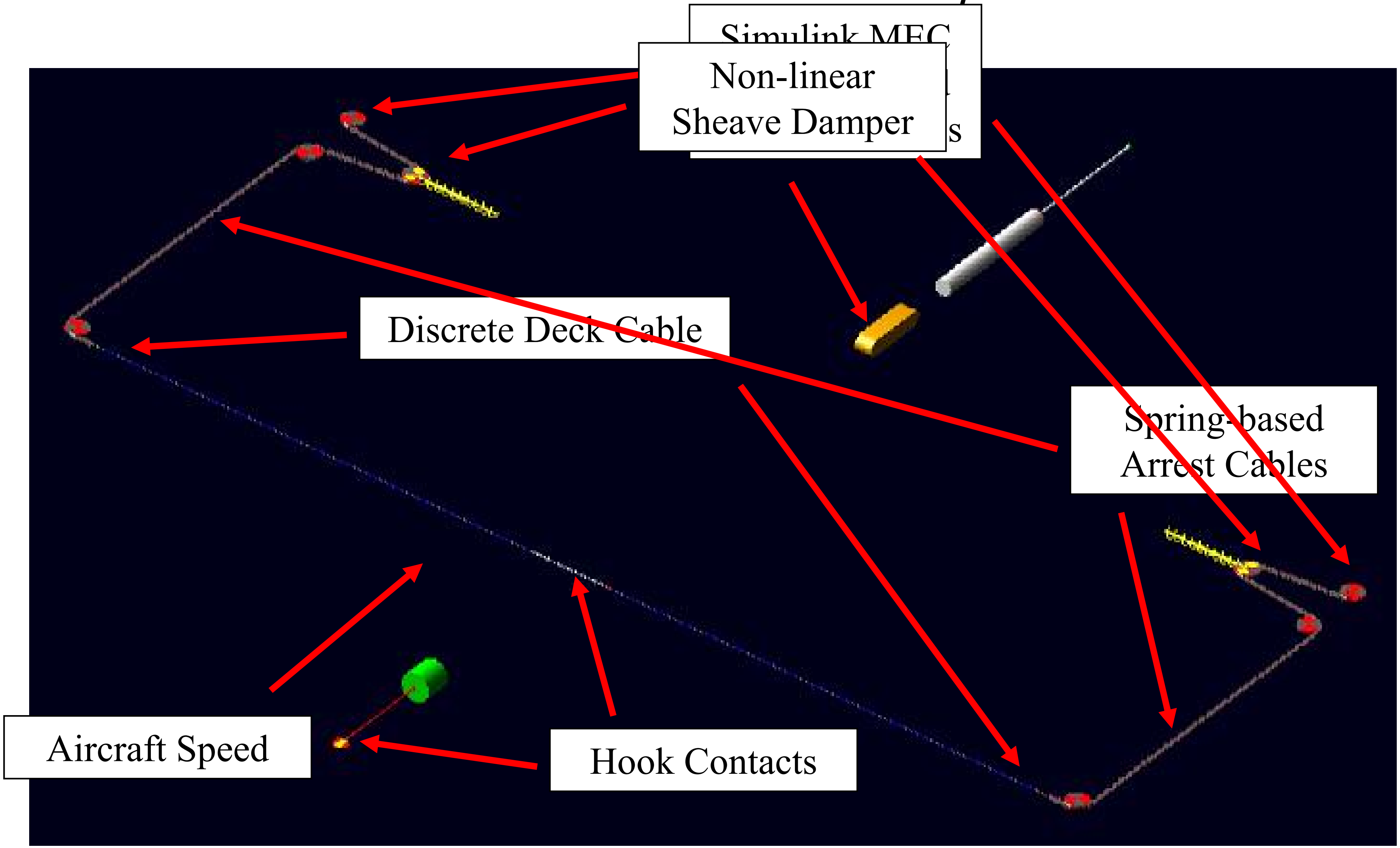
Different models defined

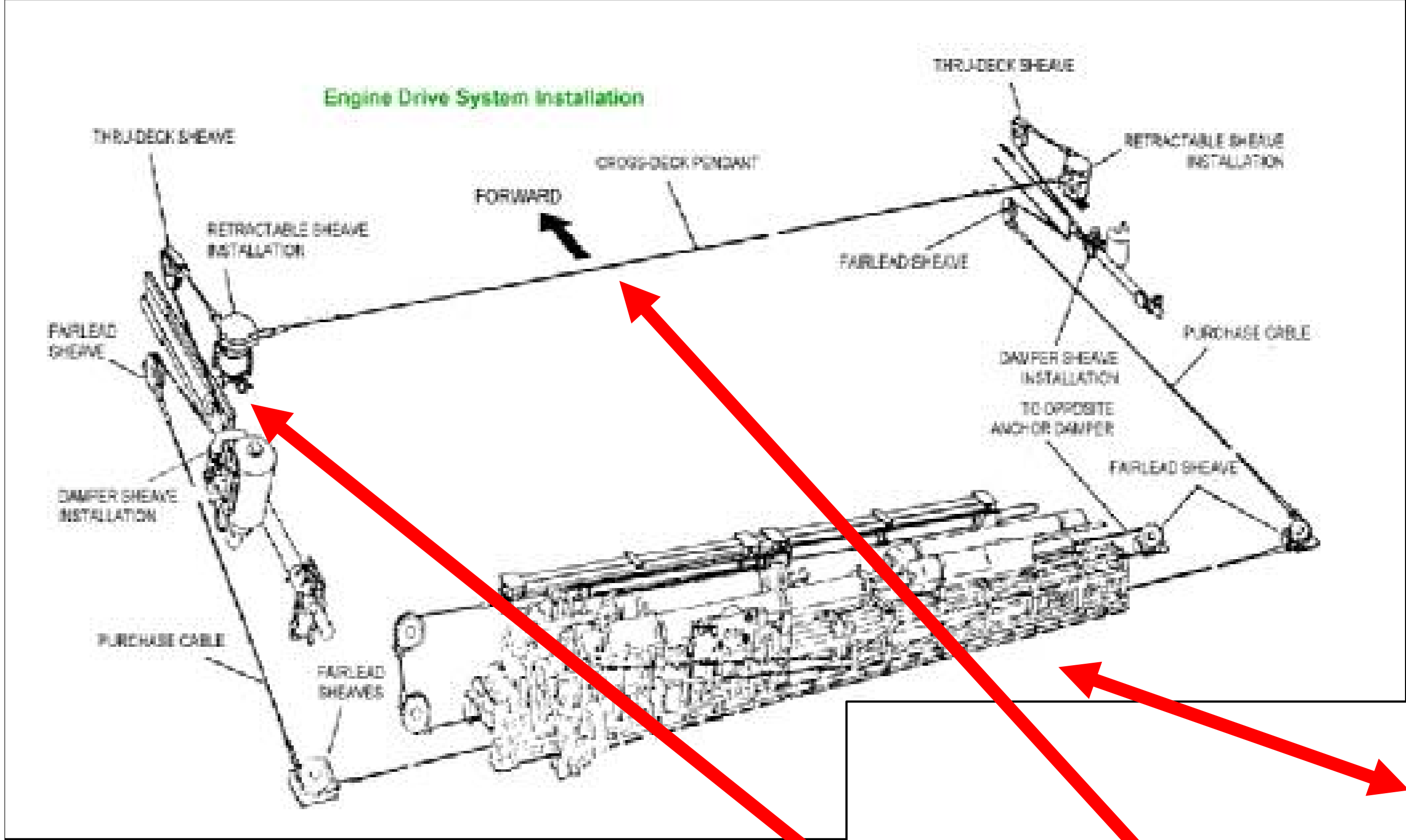
Model	**Description**
1.	Spring-based cables, non-linear sheave dampers
2.	Discrete cross-deck, simple sheave dampers
3.	Discrete cross-deck, non-linear sheave dampers
4.	Discrete cables only, simple sheave dampers
5.	*Hybrid* cables, non-linear sheave dampers

Model Components

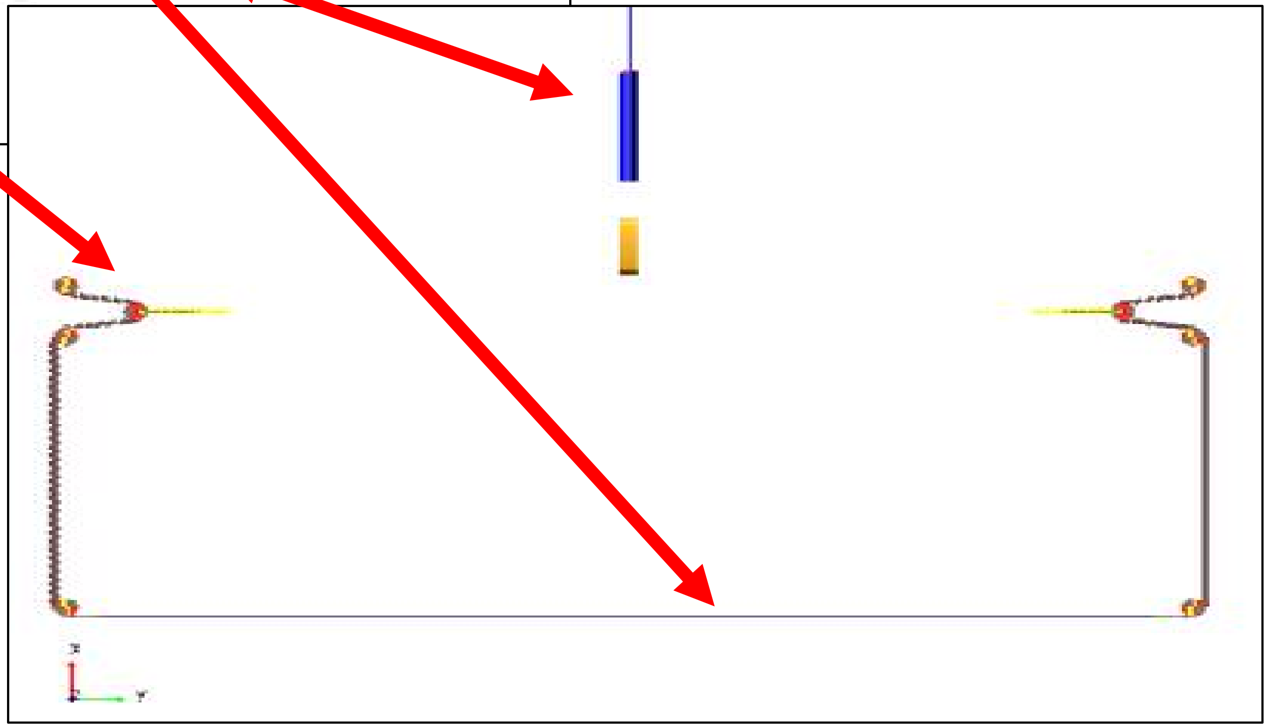


Model 3: *discrete cross-deck, non-linear sheave dampers*





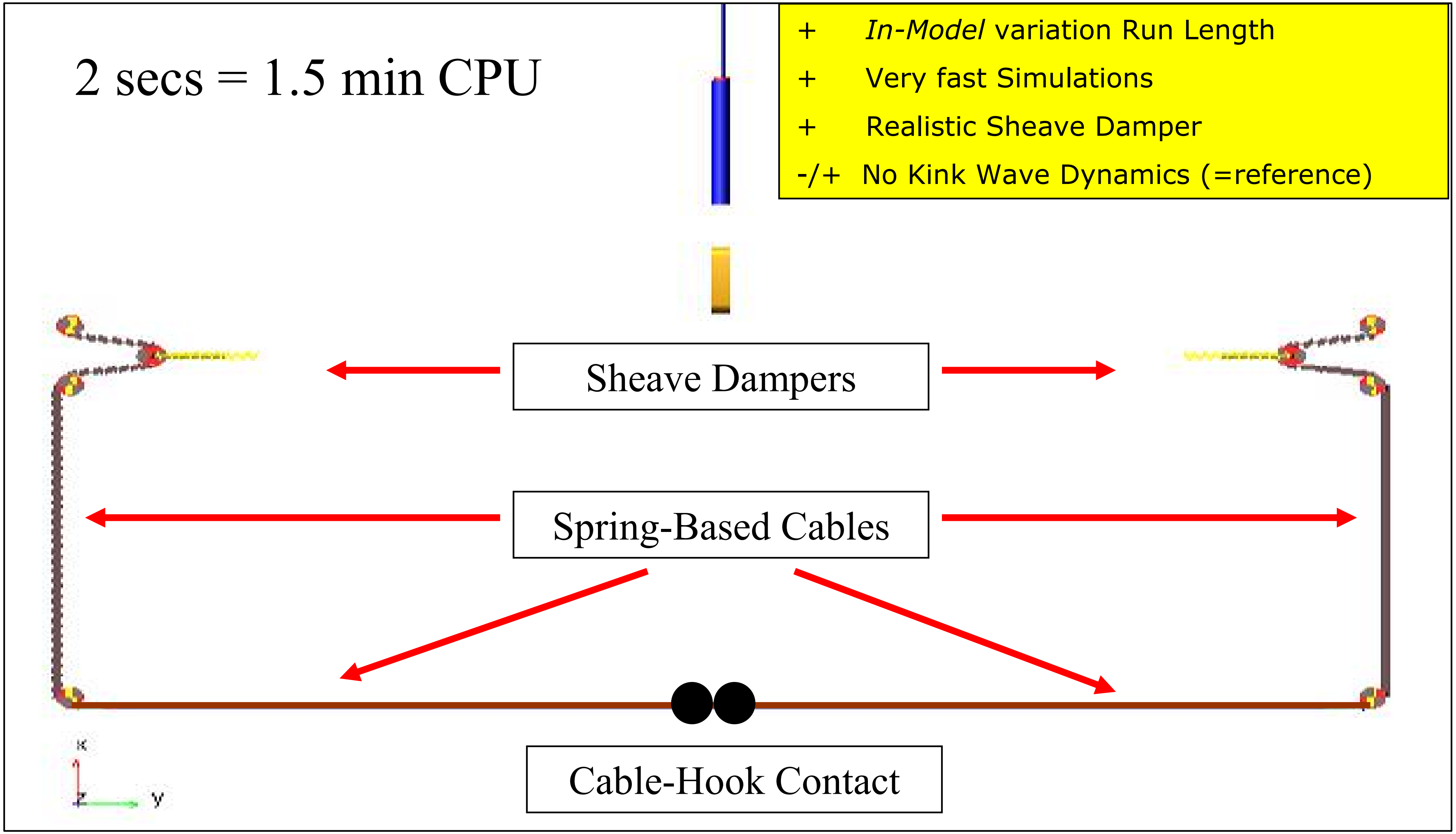
Model 3: component mapping



1: Spring-based cables, Non-Linear Sheave Dampers

2 secs = 1.5 min CPU

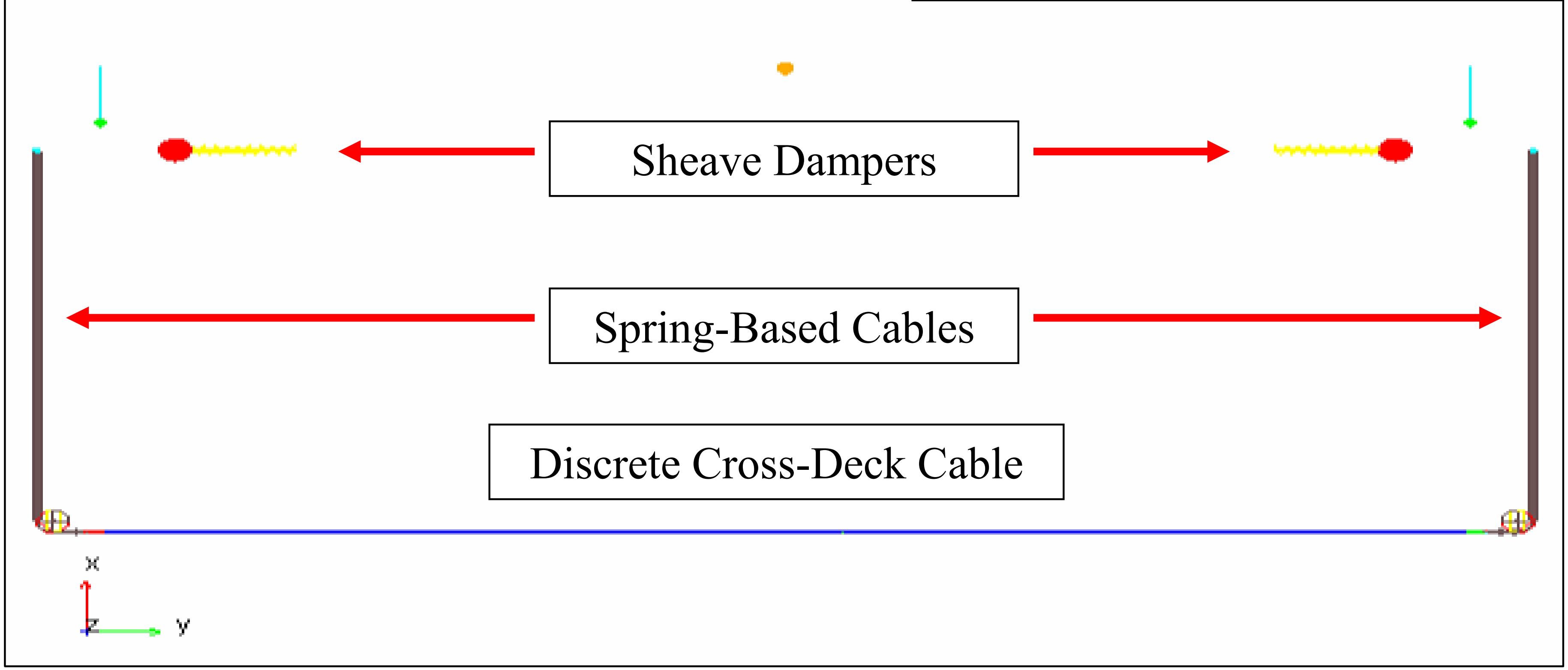
- \+ *In-Model* variation Run Length
- \+ Very fast Simulations
- \+ Realistic Sheave Damper
- -/+ No Kink Wave Dynamics (=reference)



2: Discrete Cross-deck, Simple Sheave Dampers

2 secs = 20 min CPU

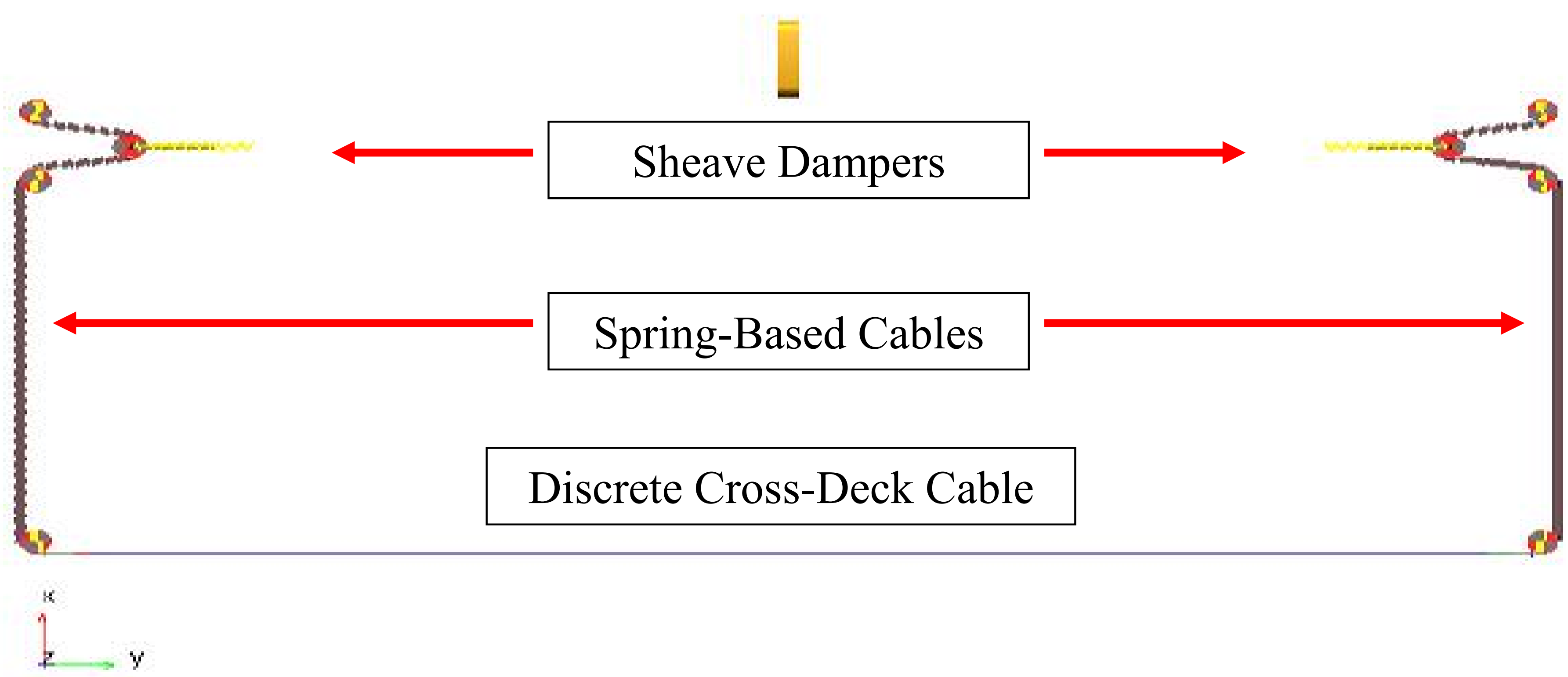
+ *In-Model* variation Run Length
+ Fast Simulations
- Partly Kink Wave Dynamics
- Simple Sheave Damper



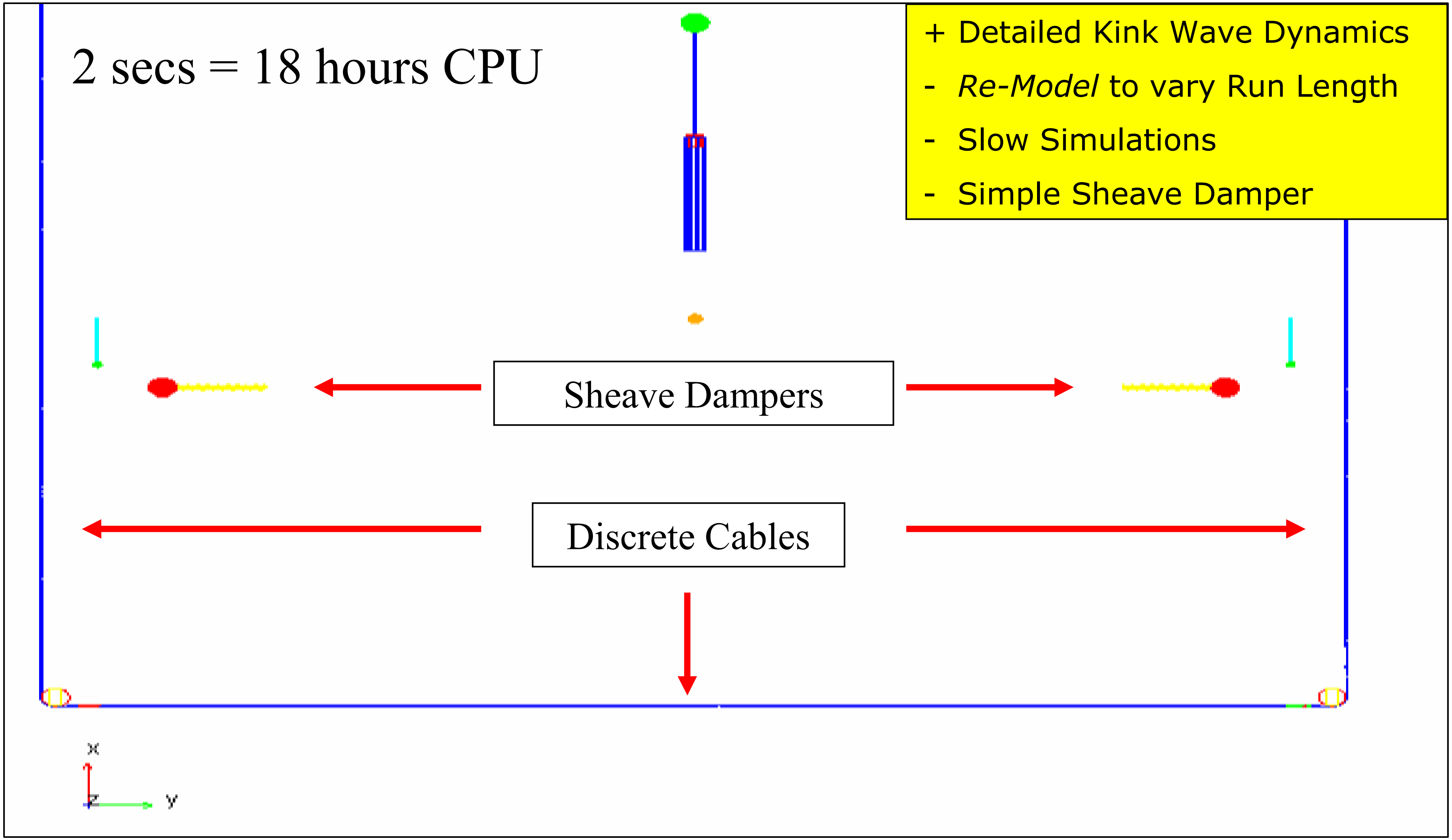
3: Discrete Cross-deck, Non-Linear Sheave Dampers

2 secs = 20 min CPU

+ *In-Model* variation Run Length
+ Fast Simulations
+ Realistic Sheave Damper
- Partly Kink Wave Dynamics



4: Discrete Cable Only, Simple Sheave Dampers

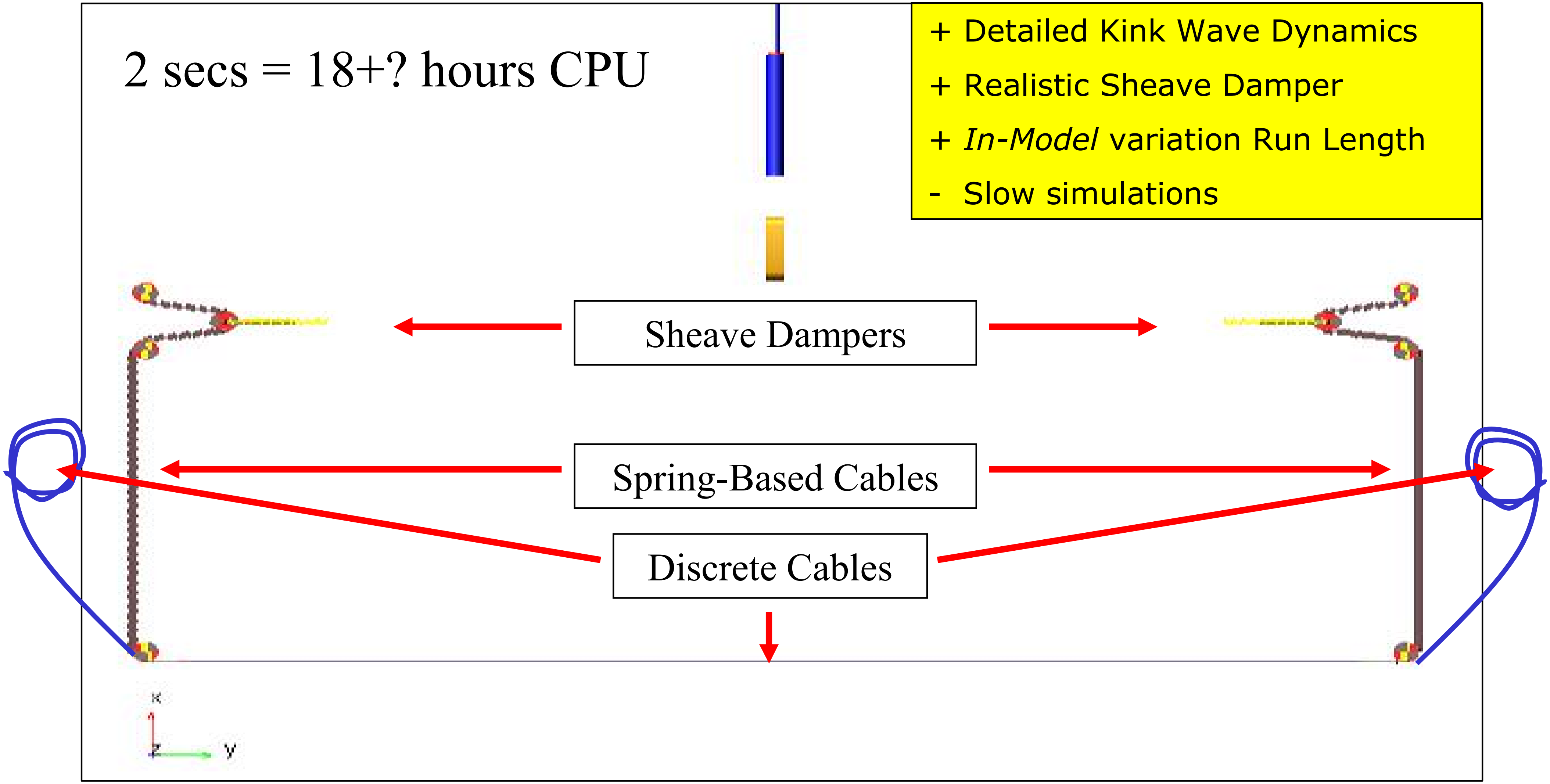


+ Detailed Kink Wave Dynamics
- *Re-Model* to vary Run Length
- Slow Simulations
- Simple Sheave Damper

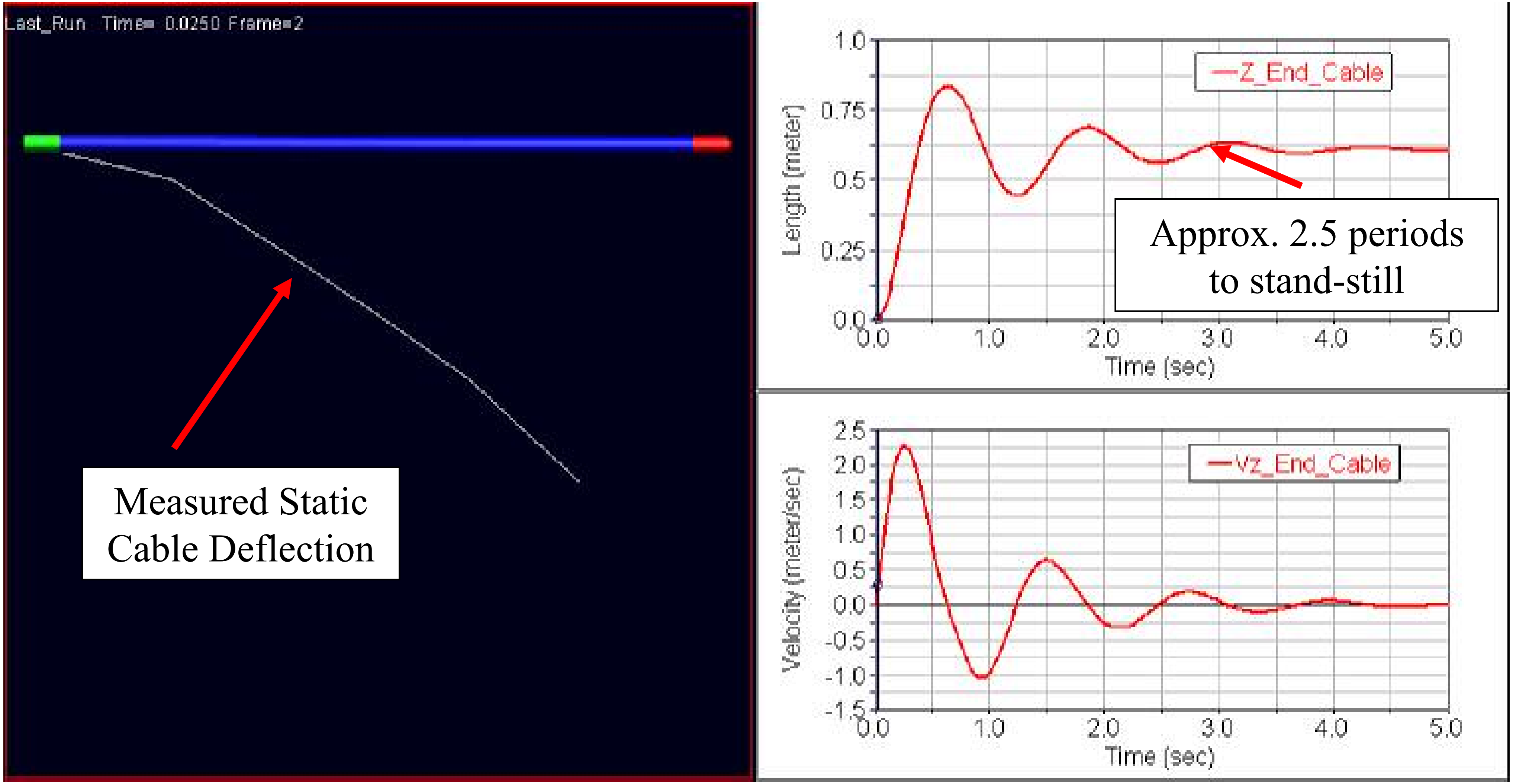
5: *Hybrid* Cable, Non-Linear Sheave Dampers
To Be Defined !!!

2 secs = 18+? hours CPU

+ Detailed Kink Wave Dynamics
+ Realistic Sheave Damper
+ *In-Model* variation Run Length
- Slow simulations



Cable Data Measurements



→ ASCII Cable Data File

```
!$The_Model:  T=model :  u=.MEC_Springs
!$Data_Name:  T=Belt_Data :  u=.MEC_Springs.Cable_Data
!
var mod var = $Data_Name.Density                real = (7801.0(kg/m**3))
var mod var = $Data_Name.Youngs                 real = (2.07E+011(N/m**2))
var mod var = $Data_Name.Axial_Factor           real = 0.5
var mod var = $Data_Name.Bend_Factor            real = 5.2E-007
var mod var = $Data_Name.Axial_Damp_Rate        real = (1.0E-002(sec))
var mod var = $Data_Name.Bend_Damp_Rate         real = (0.1(sec))
var mod var = $Data_Name.Ramp_up                real = 1.0E-005
var mod var = $Data_Name.Tooth_Pitch            real = (1.0E-002(m))
var mod var = $Data_Name.Cont_Stiff             real = (5.0E+005(N/mm))
var mod var = $Data_Name.Cont_Damp_Rate         real = (1.0E-005(s))
var mod var = $Data_Name.Cont_Expon             real = 2.9
var mod var = $Data_Name.Cont_Pene              real = (0.1(mm))
var mod var = $Data_Name.Frict_Coeff            real = 0.2
var mod var = $Data_Name.V_Slip                 real = (0.2(m/s))
var mod var = $Data_Name.Height                 real = (30(mm))
var mod var = $Data_Name.Width                  real = (30(mm))
var mod var = $Data_Name.Frc_Init               real = (1.55E+004N)
!
! ======== Last line of file : <./ACL_Data/Arrest_Cable.belt> ==============
```

Example: ASCII Aircraft Data File

```
!
!$The_Model:  T=model :  u=.My_Model
!
var Mod  var = $The_Model.Aircraft_X_Hook_Rear       real    = (35.0m)                     units = length
!
var Mod  var = $The_Model.Aircraft_Speed             real    = (146.0(mile/hour))          units = velocity
var Mod  var = $The_Model.Aircraft_Inertia           real    = (43000(pound_mass))         units = mass
var Mod  var = $The_Model.Aircraft_Thrust            real    = (20482(pound_mass))         units = force
var Mod  var = $The_Model.Aircraft_Arrest_MEC_SWS    real    = 4.7E+004                    units = no_units
!
! ======== Last line of file : <./ACL_Settings/FA_18_EF_Meas.set> ==============
!
```

+ All aircraft data stored in single ASCII File

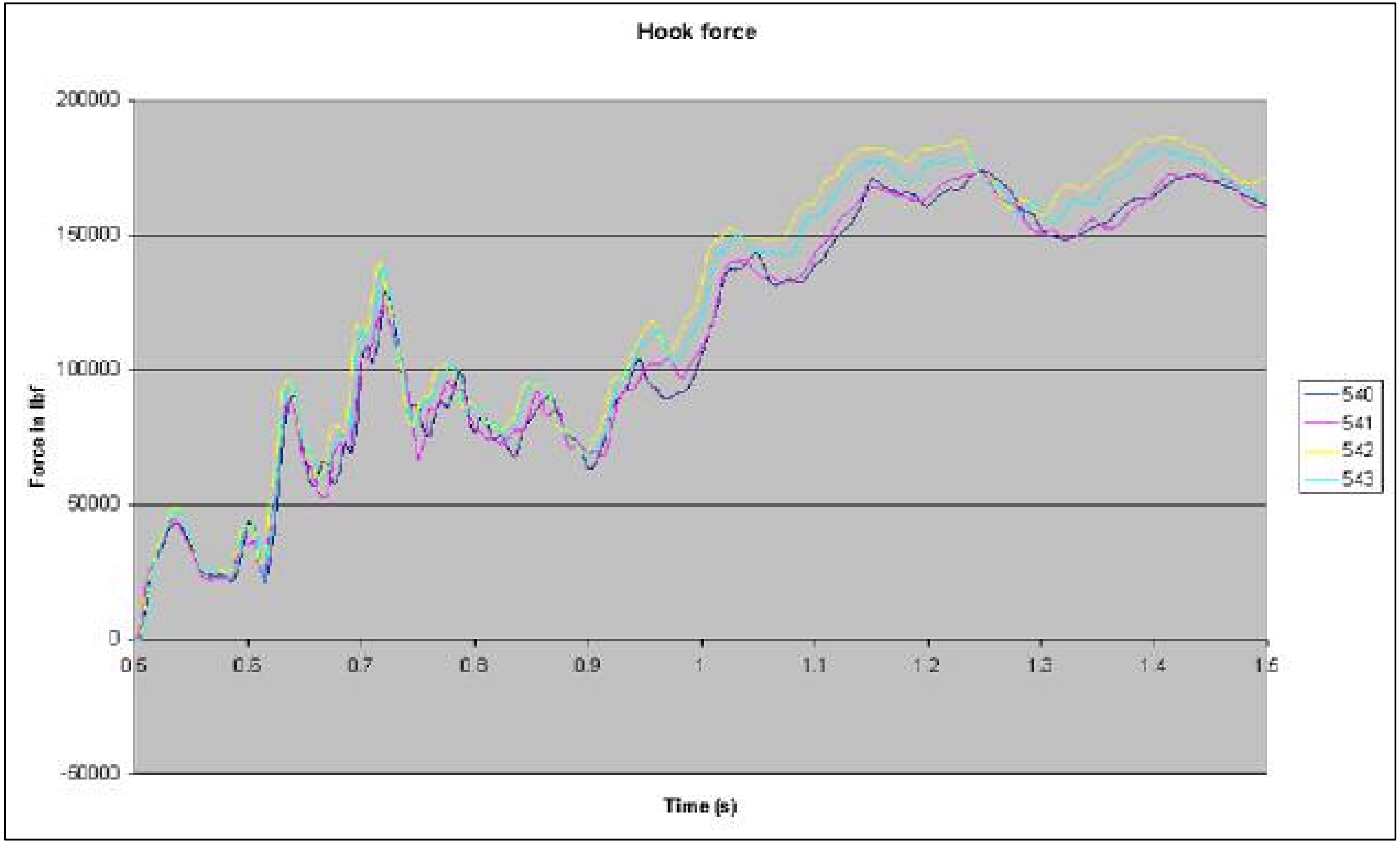
+ Usable across models and across users

+ Supports good management of simulation data

Simulation Results

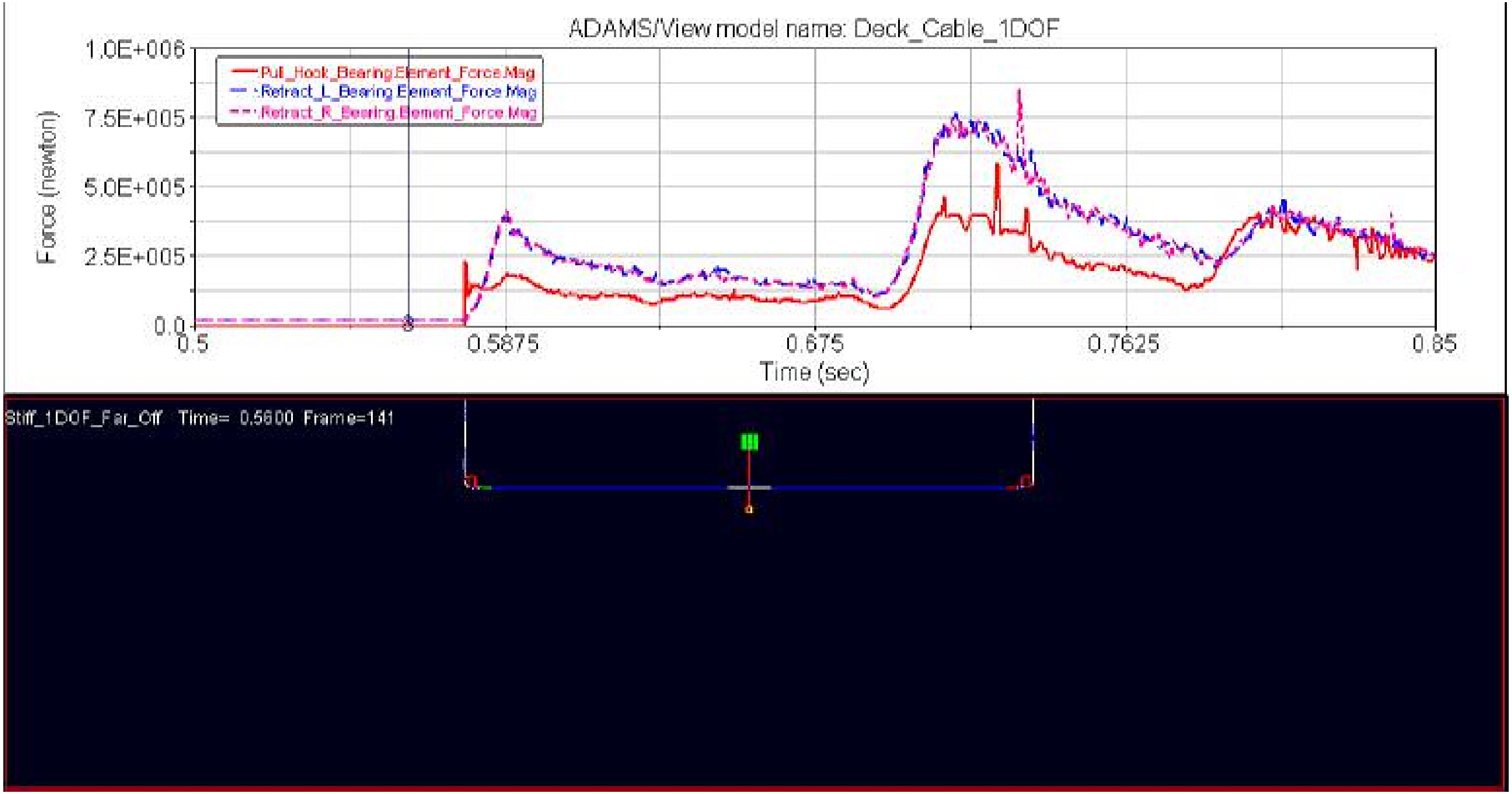
- Parameter studies:
  - Axial cable stiffness (DOF of discrete cable)
  - Transversal stiffness/damping of cables
  - Cable discretization pitch
  - Appropriate cable-to-pulley contact data
  - Aircraft settings applied

Measurement Results



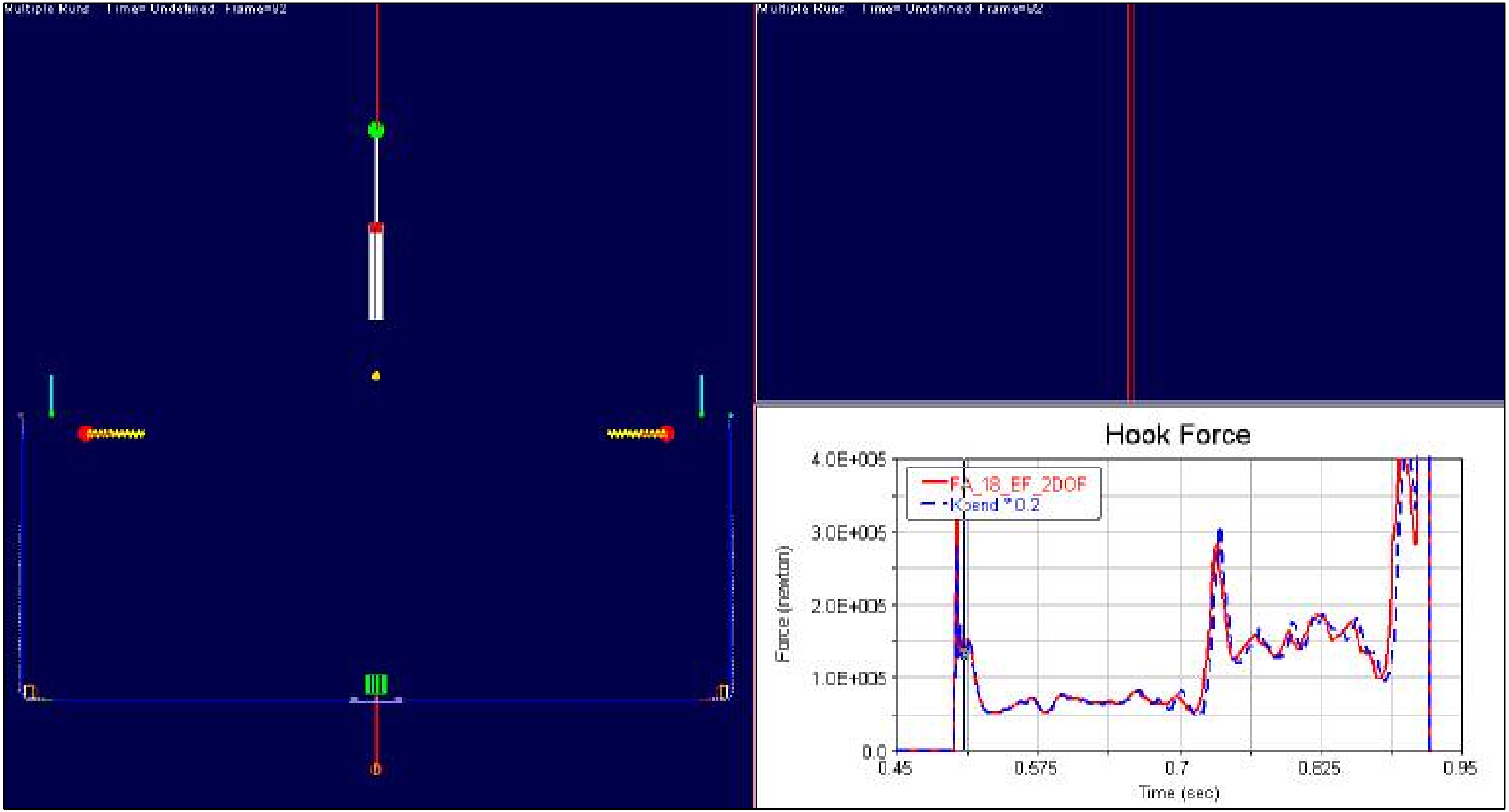
→ Excellent repeatability in measurements

Simulation Movies



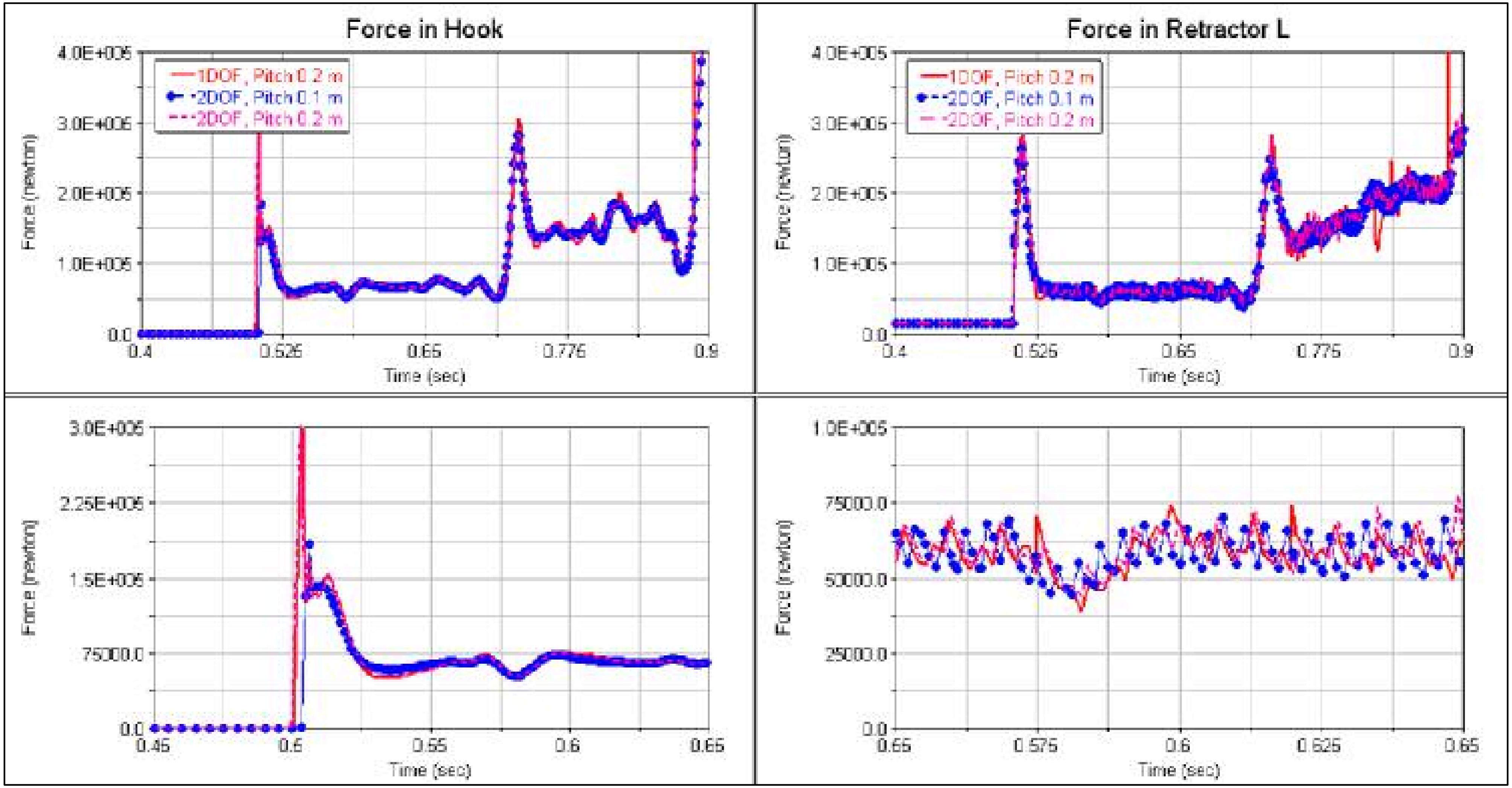
Model 4: kink wave and impacts clearly visible

Initial version of Model 4 (linear coupling to MEC)



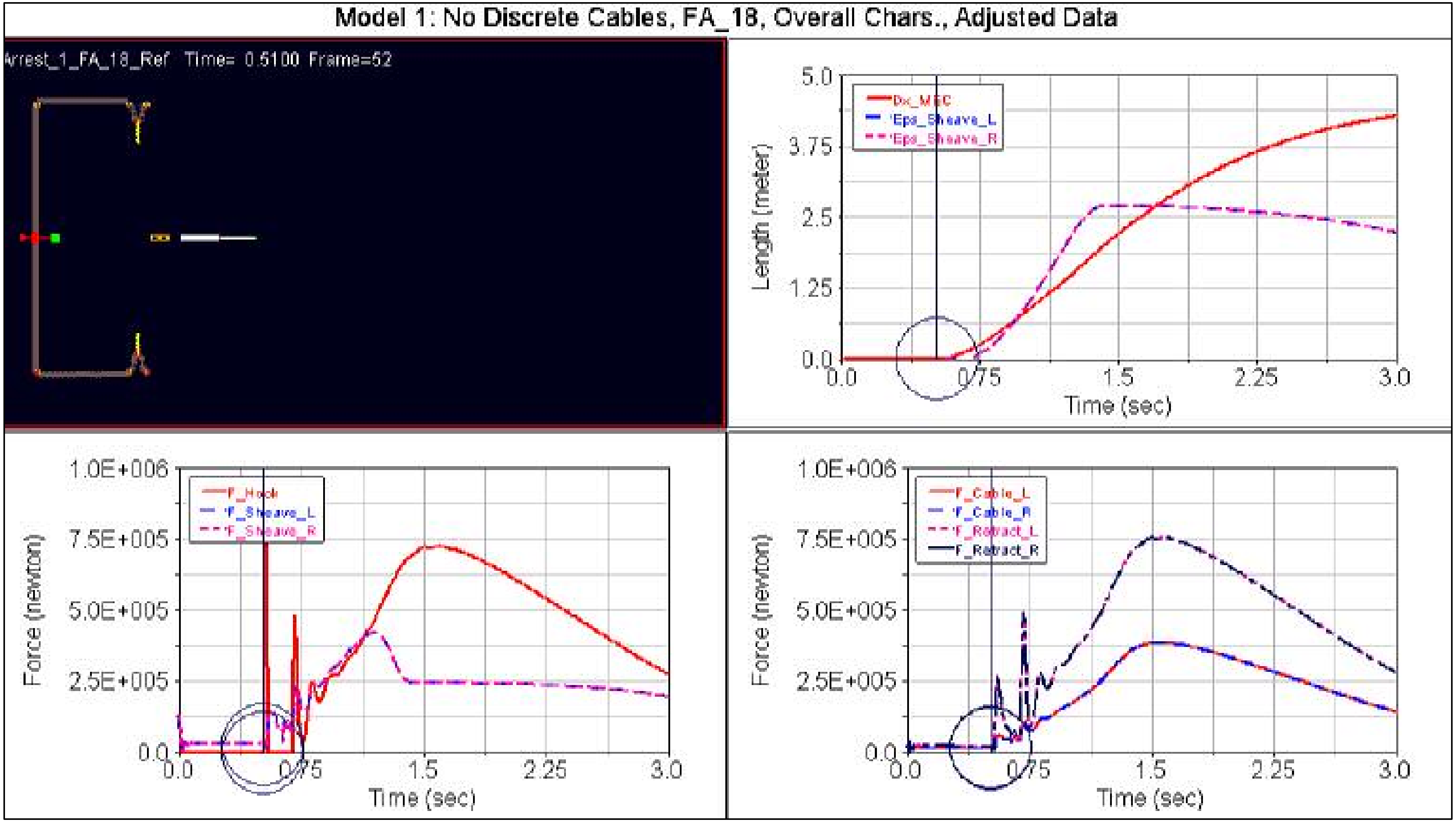
Model 4: Small effect of axial & bend stiffness on hook load

Simulation Results



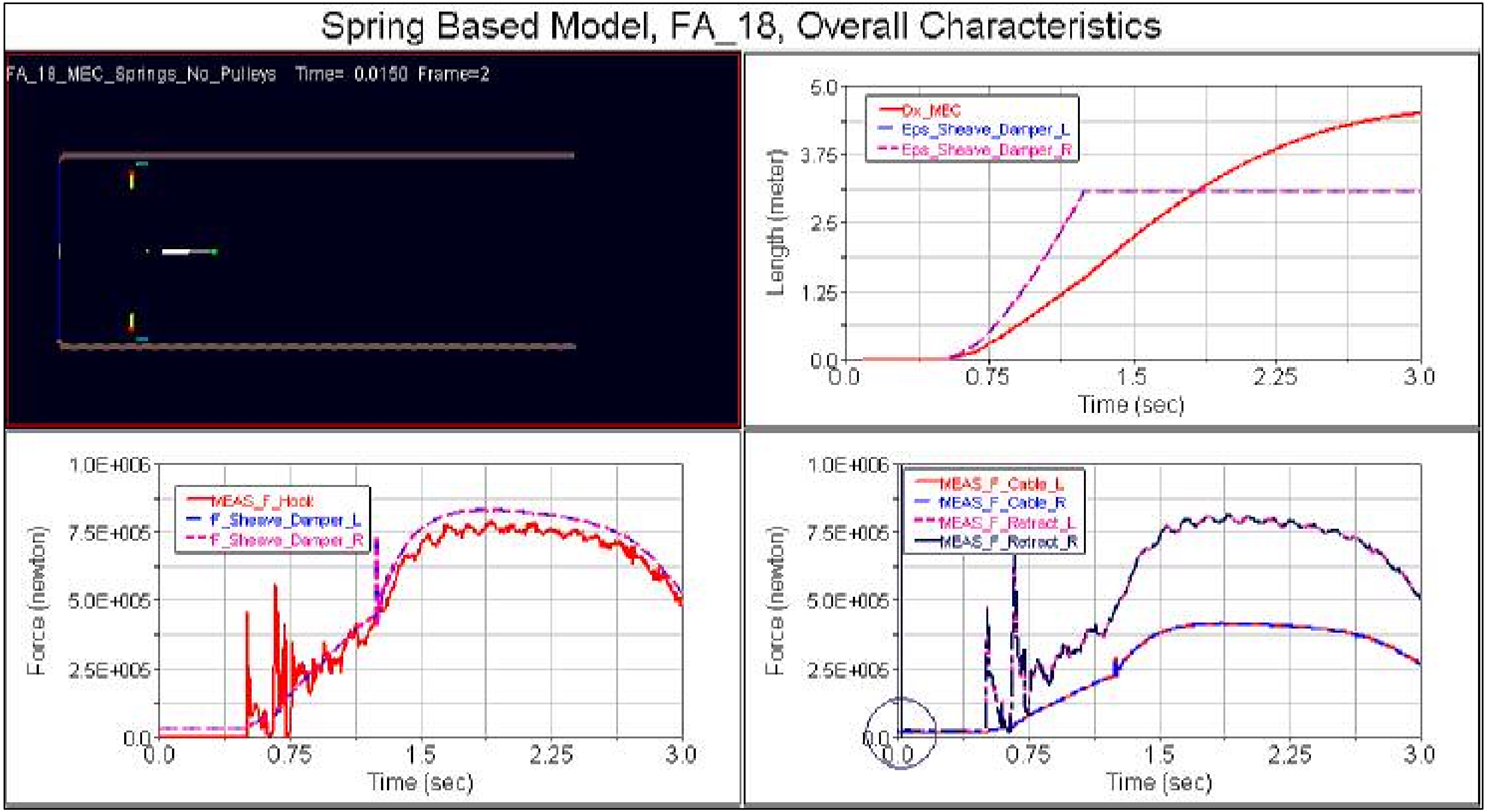
→ Minimal effect of cable Pitch & axial deformation

Model 1: overall behaviour



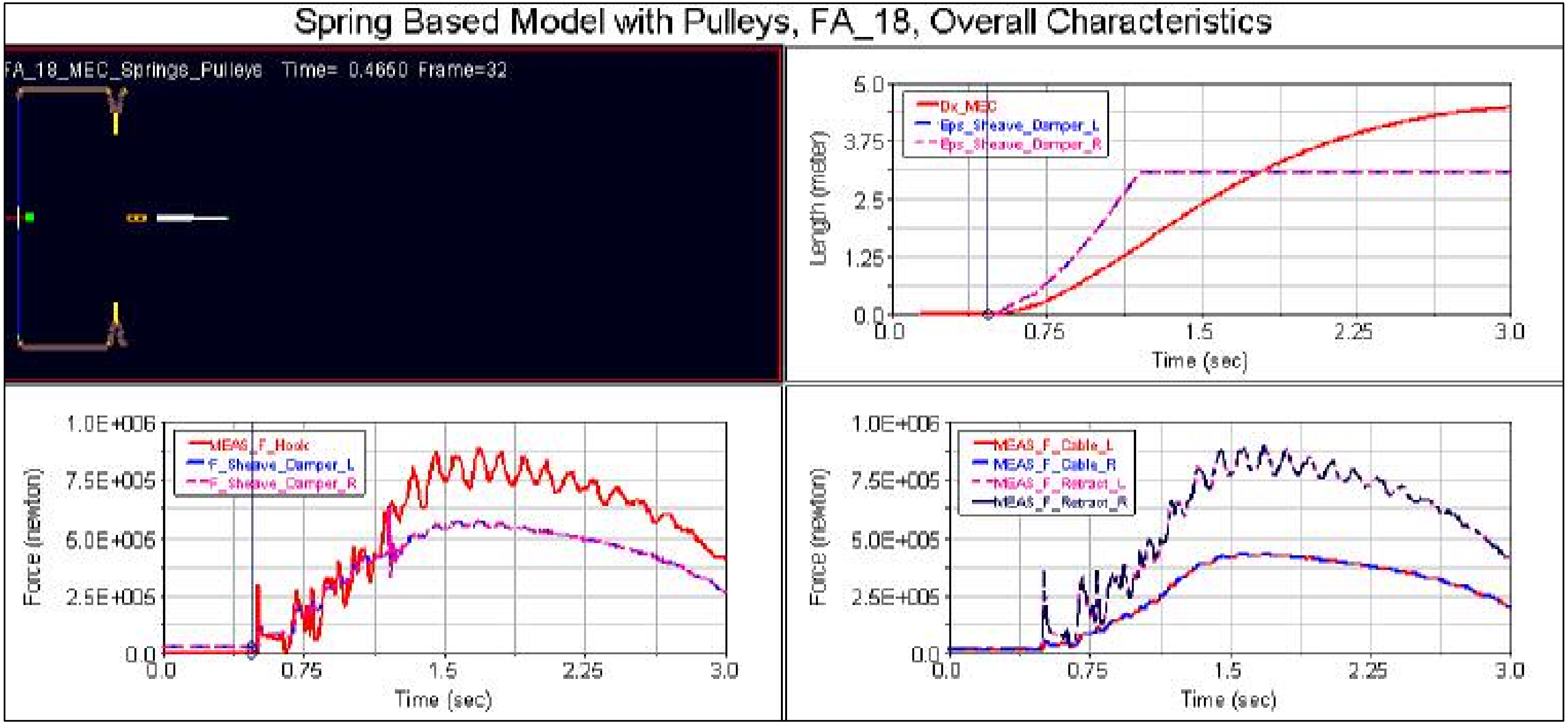
→ Model 1: fast representation of overall behaviour

Model 2: overall behaviour



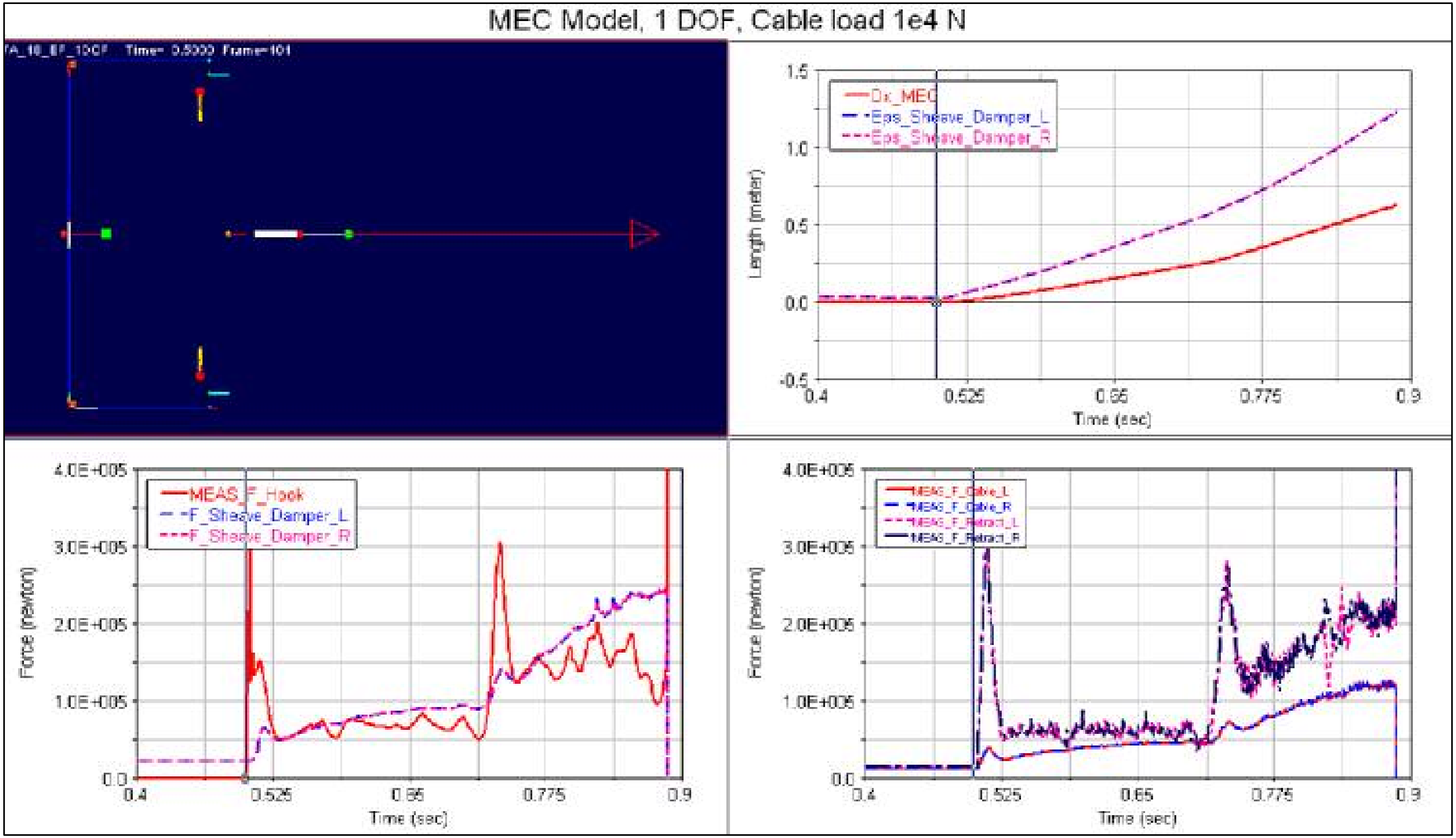
→ Model 2: deviations from sheave damper linearity

Model 3: overall behaviour



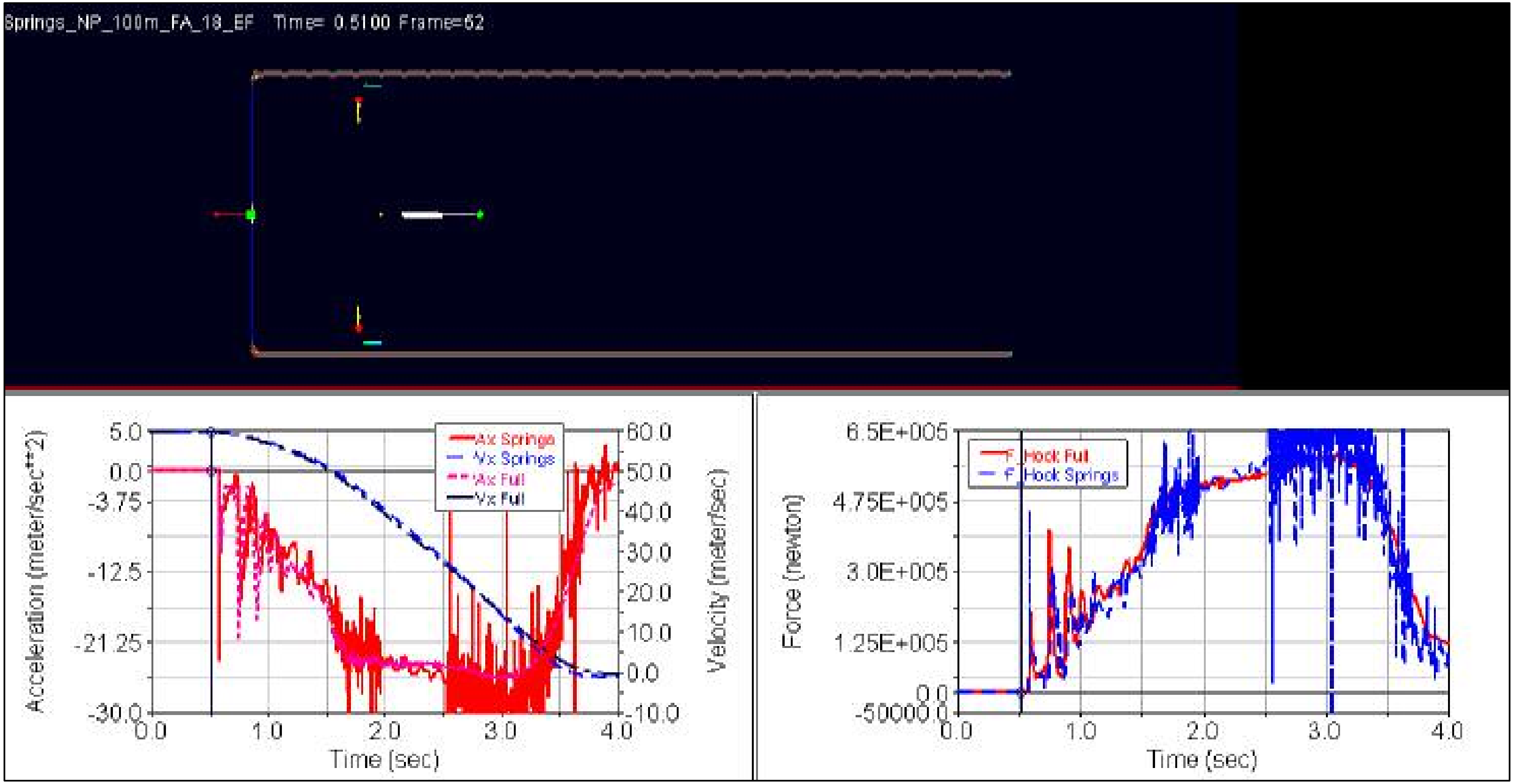
→ Model 3: Cross-deck cable dynamics slightly off

Model 4 (15 m cable): initial behaviour



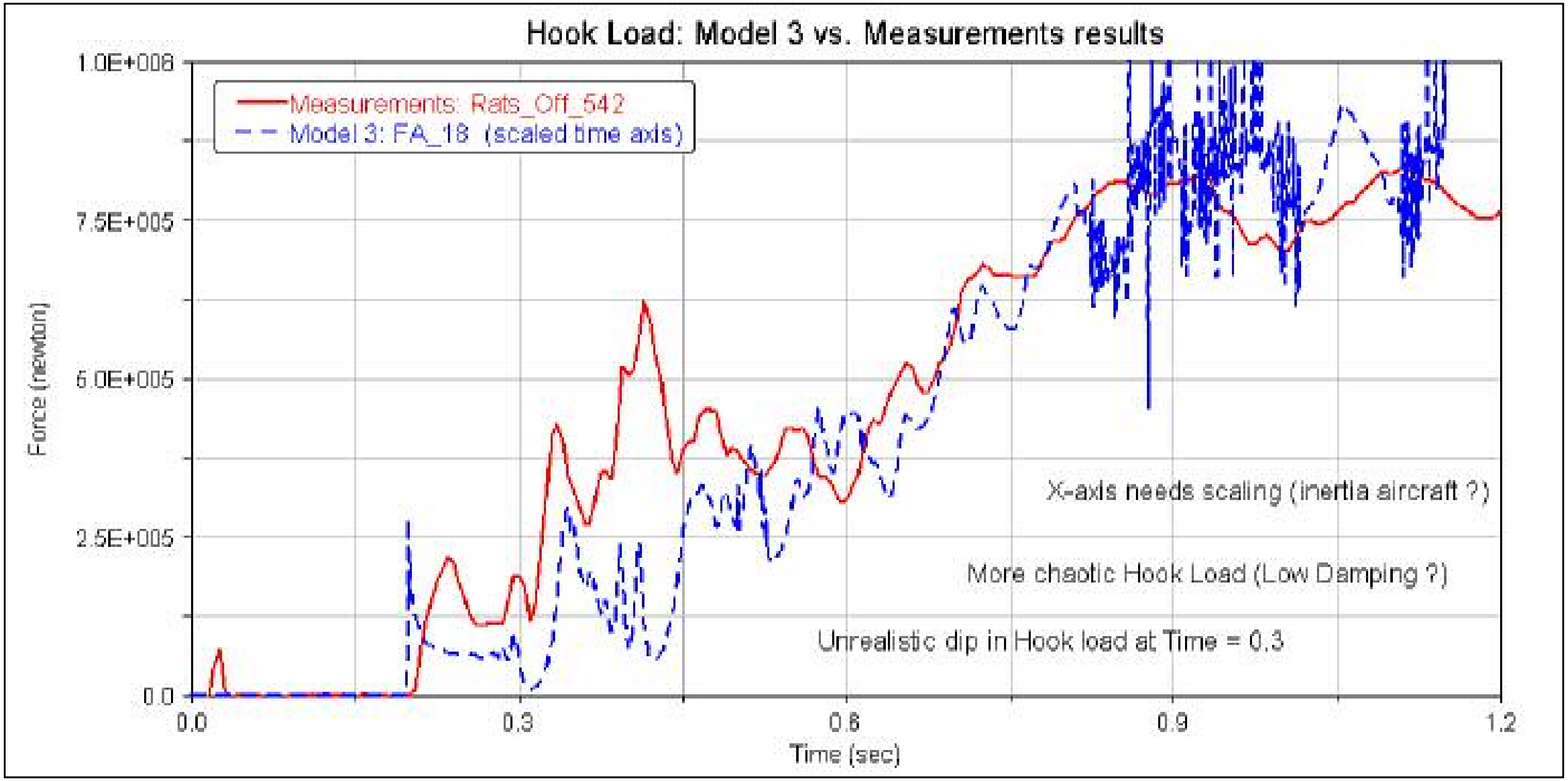
→ Model 4: Cable kink wave dynamics seems realistic

Model 2 vs. model 4



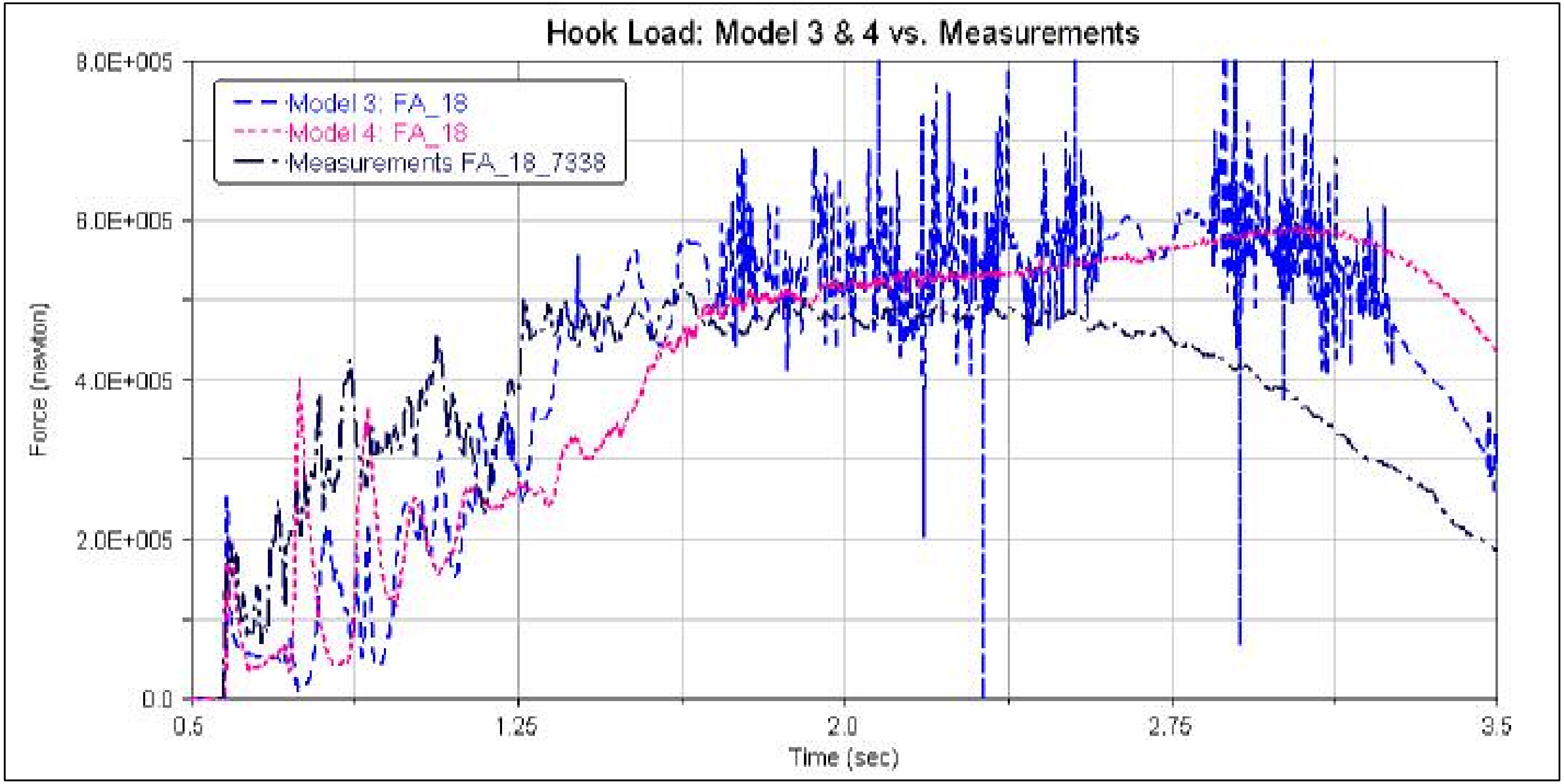
→ Discrete cables give better damping properties

Model 3 (modified) vs. measurements



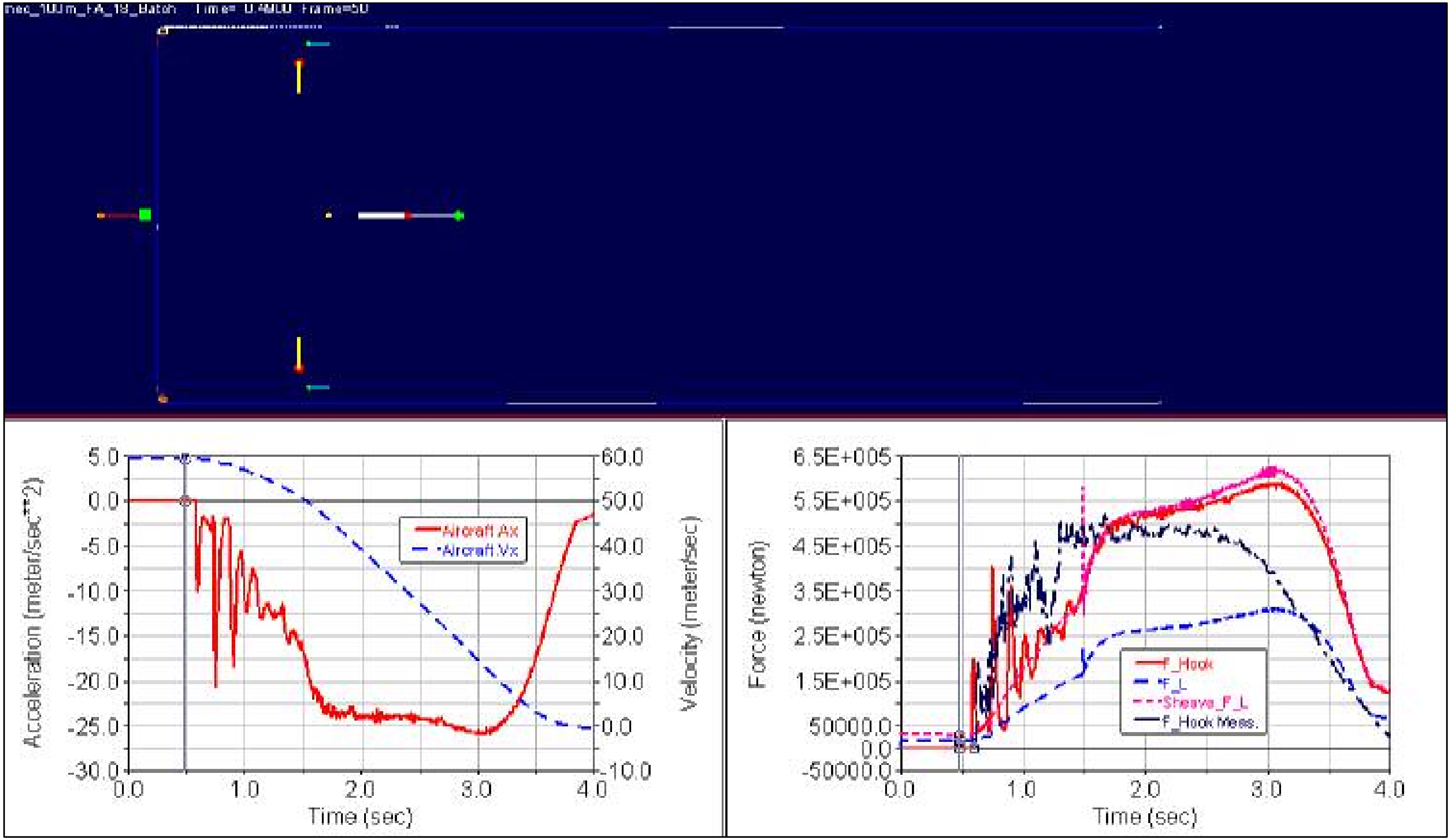
→ Startup differences model 3 vs. measured explainable

Model 3 and 4 vs. measurements



Overall differences model 3&4 vs. Measured tunable

Model 4 (100 m cable) vs. measurements



→Model parameters need tuning

Conclusions

1. Model results:
   - Use of multiple models (both complex and simple) is efficient when doing a complex simulation project;
   - The models created appear to be able to describe the kink-wave dynamic phenomenon in a way usefull for design optimisations.
2. Using a *hybrid* approach: (axial+transversal cable models) the complete arrest gear dynamics can be simulated.
3. Sensitivity studies:
   - At current settings, the influence of axial and lateral cable parameters is small;
   - The position of the sheave damper (and modelling method) has a large effect on the hook load simulated;
   - Several other parameters have to be varied and extra effects need to be modelled to achieve proper model verification.

Future work to be done

- Cable models:
  - *Hybrid* cable models: Discrete + Spring-Based
  - Parameters for Spring-Based cables: inertia at Len(t) , lateral damping/stiffness
  - Cable-pulley contacts: CPU speed up (factor 10 ?)
- System effects to be implemented:
  - Sheave friction, cable friction
- Arrest gear model components to be defined:
  - Anchor dampers
  - MEC: piston + 18 cable parts
- Model verification on Measurements